Corrosion

CONSOLIDATED CHEMICAL INDUSTRIES INC.

CCI-55

ANSWERS TO *OUR* QUESTIONS
ABOUT NO-OX-ID RUST PREVENTIVES

● Here are the high points of a discussion recently held between a Dearborn representative, who *asked* the questions and an executive engineer of a major gas line who supplied the *answers:*

Q. How long have you used NO-OX-ID?
A. Ten years.

Q. Uninterruptedly? **A.** Yes.

Q. Have you ever been disappointed? **A.** Certainly not, the results have been good.

Q. Can you name a specific performance?
A. Yes, 10 years without a leak or replacement with soil resistance at 750 to 1200 ohms per cubic centimeter.

Q. What protection did you use prior to NO-OX-ID and what was your experience?

A. Another coating that gave us an average pipe life of two years.

Q. Comparatively speaking, have you found NO-OX-ID applications cost less? **A.** Yes, not only with maintenance crews but some contractors on "big inch" lines have bid an average of five cents per foot less.

This is typical of the regard of users for NO-OX-ID Rust Preventives in every pipe line service.

Consult with your Dearborn Engineer. There are versatile NO-OX-ID coating combinations for new or reconditioned lines ... hot or cold application ... for every climate and soil condition.

DEARBORN CHEMICAL COMPANY
General Office: 310 S. Michigan Ave., Chicago 4, Ill.
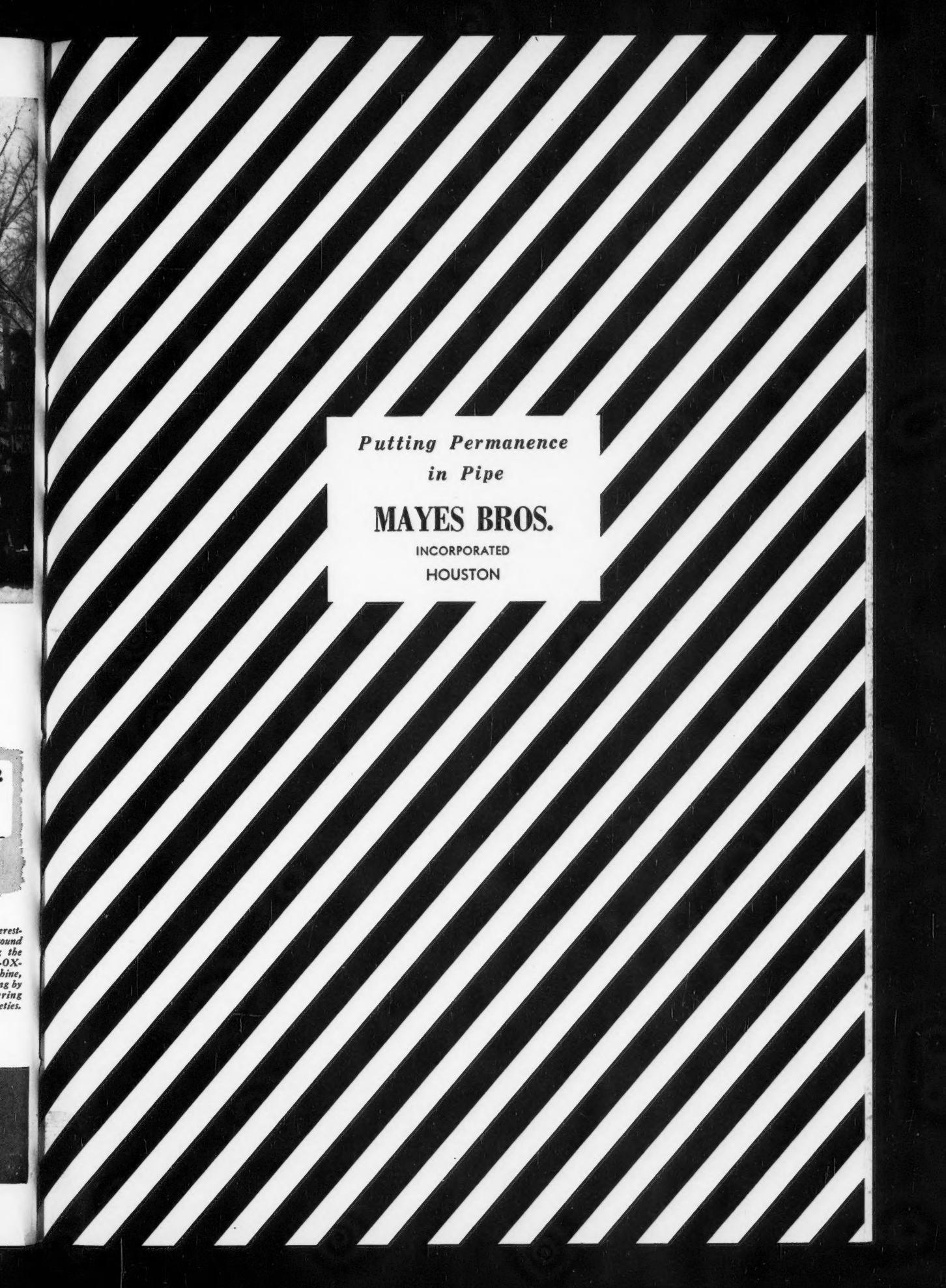
"PIPING HOT"

"Piping Hot," an interesting, full-color, 16 mm sound movie demonstrating the use of hot applied NO-OX-IDs by stationary machine, is available for booking by companies, engineering clubs or technical societies. Write ...

Dearborn
Reg. U.S. Pat. Off.

NO-**OX**-ID
IRON + **OX** = RUST

THE ORIGINAL
RUST PREVENTIVE

THIS MONTH'S COVER—The second of two barges built for Consolidated Industries, Inc., Houston, Texas by Dravo Corp., Pittsburgh, slides into the Ohio River. The barges contain two cylindrical steel tanks cradled longitudinally with approximately 114,000-gallon capacity. Corrosion damage through acid spillage is minimized by an outboard-sloping watertight steel deck with a 3-inch-in-15-feet camber. Only diluted acid in bilges or elsewhere presented a major corrosion threat. The large tanks reduce piping and help reduce cargo discharge time. Loaded draft is 8 feet.

☆

CONTENTS

Directory of NACE Regional and Sectional Officers

NORTH EAST REGION

R. H. LYNCH, Director
Keystone Pipe Line Co.,
260 South Broad Street,
Philadelphia 1, Penna.

LEWIS B. DONOVAN, Chairman
Consolidated Edison Co.
of New York Inc.,
4 Irving Place,
New York 3, N. Y.

HUGH L. HAMILTON,
Vice-Chairman
Keystone Pipe Line Co.,
260 S. Broad St.,
Philadelphia, Pa.

E. ROWLAND ENGLISH,
Sec.-Treas.
H. C. Price Co.,
P. O. Box 6120,
Philadelphia 15, Pa.

● Metropolitan Section
(N.Y.)

T. P. MAY, Chairman
International Nickel Co., Inc.
67 Wall Street
New York 5, N. Y.

H. W. WAHLQUIST, Vice-Chair.
Ebasco Services, Inc.,
2 Rector Street,
New York, N. Y.

F. J. LeFEBVRE, Sec.-Treas.
Electro Rust-Proofing Corp.
(N. J.)
1 Main Street,
Belleville 9, N. J.

● Philadelphia Section

ROBERT R. PIERCE, Chairman
Pennsylvania Salt Mfg. Co.,
1000 Widener Bldg.,
Philadelphia, Pa.

HENRY F. McCONOMY, Vice-Chair.
The Atlantic Refining Co.,
P. O. Box 8138,
Philadelphia, Pa.

ERNEST H. WYCHE, Sec.-Treas.
Lukens Steel Co.,
Coatesville, Pa.

● Baltimore Section

EDGAR F. WOLF, Chairman
Cons. Gas Electric Light and
Power Co. of Baltimore,
531 East Madison St.,
Baltimore 3, Md.

HOMER D. HOLLER, Vice-Chairman
National Bureau of Standards,
Room 207, East Building,
Washington 25, D. C.

GEORGE E. BEST, Sec.-Treas.
Mutual Chemical Co. of Am.,
1348 Block Street,
Baltimore 31, Md.

● Pittsburgh Section

RUSSELL H. COE, Chairman
Pittsburgh Coke & Chemical
Co., P. O. Box 1645,
Pittsburgh 19, Pa.

V. V. KENDALL, Vice-Chairman
National Tube Co.,
Box 266,
Pittsburgh, Pa.

J. M. BIALOSKY, Treasurer
Carnegie-Illinois Steel
Corp., 210 Semple St.,
Pittsburgh 13, Pa.

E. D. VERINK, JR., Secretary
Aluminum Co. of America,
P. O. Box 1012,
New Kensington, Pa.

W W. BINGER, Asst. Secretary
Research Laboratories,
Aluminum Co. of America,
New Kensington, Pa.

NORTH CENTRAL REGION

FRANK L. WHITNEY, Jr., Dir.,
Monsanto Chemical Co.,
1700 S. Second St.,
St. Louis, Mo.

L. G. VANDE BOGART, Chairman
Crane Co., Engineering & Res.
Div., 836 South Michigan Ave.
Chicago 5, Illinois

WALTER J. SANDEL, Vice-Chair.
Coatings for Industry, Inc.
2185 East 18th Street,
Cleveland 15, Ohio

R. A. SHOAN, Sec.-Treas.
Dearborn Chemical Company,
1029 West 35th Street,
Chicago 9, Illinois

● Chicago Section

VICTOR J. PAYTON, Chairman
Comonwealth Edison Co.,
72 West Adams St.,
Chicago, Ill.

FRANKLIN M. WATKINS,
Vice-Chair.
Sinclair Refining Co.,
400 East Sibley Blvd.,
Harvey, Ill.

C. A. VAN NATTA, Secretary
Plastic Lining Corp.,
914 South Wabash Ave.,
Chicago, Ill.

LAURIE E. NICHOLLS, Treasurer
Public Service Corp. of
Northern Illinois,
1001 South Taylor Ave.,
Oak Park, Ill.

● Cleveland Section

RAYMOND B. HOXENG, Chairman
Case Institute of Tech.,
University Circle,
Cleveland, Ohio

L. W. DAVIS, Vice-Chairman
Aluminum Co. of Am.,
2210 Harvard Ave.,
Cleveland, Ohio

CHARLES N. DETRICK, Sec.-Treas.
Williams & Co., Inc.,
3700 Perkins Ave.,
Cleveland, Ohio

● Greater St. Louis Section

FRANK L. WHITNEY, Chairman
Monsanto Chem. Co.,
1700 S. Second St.,
St. Louis, Mo.

GEORGE FISHER, Vice-Chair.
The International Nickel Co.,
411 N. 7th St.,
St. Louis, Mo.

CHARLES SWARTOUT, Secretary
Mallinckrodt Chem. Co.,
3600 N. 2nd St.,
St. Louis, Mo.

GEORGE PURDY, Treasurer
Tretolite Company,
937 Pacific Ave.,
St. Louis 19, Missouri

SOUTH EAST REGION

JAMES T. MacKENZIE, Director
Amer. Cast Iron Pipe Co.,
P. O. Box 2603,
Birmingham 3, Alabama

J. W. YELDELL, Chairman
Southern Natural Gas Co.,
Box 2563,
Birmingham, Ala.

E. P. TAIT, Vice-chair.
Alloy Steel Prod. Co.,
Candler Bldg.,
Atlanta, Ga.

J. F. JOHNSTON, Sec.-Treas.
Am. Telephone & Tel. Co.,
51 Ivy St., N. E.,
Atlanta, Ga.

SOUTH CENTRAL REGION

T. F. P. KELLY, Director
James E. Mavor Co.,
Houston, Texas

TOM R. STATHAM, Chairman
Magnolia Pipe Line Co.,
Dallas, Texas

GEORGE A. MILLS, Vice-Chair.
Central Power & Lt. Co.,
Corpus Christi, Texas

M. C. FLEMING, Sec.-Treas.
Phillips Petroleum Co.,
Bartlesville, Okla.

HARRY E. WALDRIP, Ast. Sec.-
Treas.
Gulf Oil Corp.,
Houston, Texas

● Tulsa Section

F. T. GARDNER, Chairman
University of Tulsa,
Tulsa, Okla.

F. E. PYEATT, JR., Vice-Chairman
Mid-Continent Pipe Line Co.
P. O. Box 381
Tulsa 2, Okla.

FRANK E. McNULTY, Sec.-Treas.
Pittsburgh Coke & Chem. Co.
Room 711, Thompson Bldg.,
Tulsa, Okla.

● Houston Section

OLIVER OSBORN, Chairman
Dow Chemical Company,
Freeport, Texas

P. P. SPAFFORD, Vice-Chair.
Stanolind Oil & Gas Co.
Box 3092,
Houston, Texas

LAYTON C. TUGGLE, Sec.-Treas.
Shell Oil Refinery,
Box 2527,
Houston, Texas

● University of Houston
Junior Section

WM. G. BOYD, JR., Chairman

FRED KRCH, Vice-Chair.
National Lead Co.,
City National Bank Bldg.,
Houston, Texas

EMMETT O. BAMMEL, JR., Treas.
1806 Colquitt St.,
Houston, Texas

EDW. J. MULVANEY, JR., Sec.
606 S. Kansas St.,
Pasadena, Texas

JOHN P. ROBERTS, Sr. Fac. Adv.
Assoc. Prof. Metallurgy,
111 East 22nd St.,
Houston, Texas

● Shreveport Section

H. V. BEEZLEY, Chairman
United Gas Pipe Line Co.
Box 1047
Shreveport, La.

JOSEPH A. CREEVY, Vice-Chair.
Youngstown Sheet & Tube Co.
P. O. Box 44
Shreveport, La.

TOM HOLCOMBE, Secretary
Holcombe & Stearns, Inc.
Box 1306,
Shreveport, La.

M. J. OLIVE, Treasurer
Arkansas Natural Gas Co.,
Shreveport, La.

● North Texas Section

K. D. WAHLQUIST, Chairman
6281 Revere Place
Dallas 14, Texas

JOHN R. LIGON, Vice Chair.
Sinclair Ref. Co.
901 Fair Bldg.
Ft. Worth, Texas

JOHN L. POOL, Sec.-Treas.
Magnolia Pipe Line Co.
618 Magnolia Bldg., Box 900
Dallas, Texas

N. H. SIMPSON, Asst. Sec.-Treas.
Consol. Vultee Aircraft Corp.
Grants Lane
Ft. Worth, Texas

● Corpus Christi Section

JOHN G. CAMPBELL, Chairman
Box 1913,
Corpus Christi, Texas

BUFORD P. LEDBETTER, Vice-Chair.
Gas Department, City of
Corpus Christi, Texas

THOMAS S. MOFFAT, Sec.-Treas.
Southern Alkali Corp.,
Lawrence Drive,
Corpus Christi, Texas

● Permian Basin Section

AARON GENSBERG, Chairman
Gulf Oil Corp.,
Drawer 4232
Odessa, Texas

H. D. MURRAY, Vice-Chair.
The Texas Co.,
Box 1270
Midland, Texas

ROY H. ZUEFELDT, Sec.-Treas.
The Texas Co.,
P. O. Box 903,
Jal, New Mexico

(Continued Next Page)

1—North East
2—North Central
3—South East
4—South Central
5—Western

Directory of Technical Practices Committee Officers

M. G. FONTANA, Chairman
The Ohio State University,
Columbus 10, Ohio

EX-OFFICIO MEMBERS

VANCE N. JENKINS
N. E. BERRY
A. B. CAMPBELL

(Chairman of all TP sub-committees listed below are members of the full committee)

TP-1 CORROSION OF OIL AND GAS WELL EQUIPMENT (Formerly Condensate Well Corrosion)

TED S. ZAJAC, Chairman.
Shell Oil Corp., P. O. Box 2099,
Houston, Texas

TP-1A Pacific Coast. E. O. Kartinen, Chairman. Signal Oil & Gas Co., 811 W. Seventh St., Los Angeles 55, Cal.

TP-1B Condensate Well Corrosion. R. C. Buchan, Chairman. Humble Oil & Ref. Co., Houston, Texas.

TP-1C Sweet Oil Well Corrosion. H. L. Bilhartz, Chairman. Altantic Refining Co., Dallas, Texas.

TP-1D Sour Oil Well Corrosion. H. D. Murray, Chairman. Cren-Ray Plastic Prod. Co., Midland, Texas.

TP-1E Bi-Metallic Galvanic Corrosion in Oil and Gas Wells. W. F. Rogers, Chairman. Gulf Oil Corp., Drawer 2100, Houston, Texas.

TP-1F Metallurgy—Oil and Gas Well Equipment. V. V. Kendall, Chairman. National Tube Co., Box 266, Pittsburgh, Pa.

TP-2 GALVANIC ANODES FOR CATHODIC PROTECTION

WALTER P. NOSER, Chairman.
Humble Pipe Line Co., Drawer 2220,
Houston, Texas

TP-2A To Correlate Data From Operating Installations. L. R. Sheppard, Shell Pipe Line Corp., Houston, Texas.

TP-3 ANODES FOR IMPRESSED CURRENTS

DONALD H. BOND, Chairman.
The Texas Pipe Line Company,
P. O. Box 2332, Houston 1, Texas

TP-4 MINIMUM CURRENT REQUIREMENTS FOR CATHODIC PROTECTION

J. M. PEARSON, Chairman
Sun Oil Co.,
Bishop Hollow Road,
Newton Square, Pa.

TP-5 CORROSION PROBLEMS INVOLVED IN PROCESSING AND HANDLING CHEMICALS

MARS G. FONTANA, Chairman.
The Ohio State University,
Columbus 10, Ohio

TP-5A Materials for Handling and Manufacturing Sulfuric Acid. S. W. Shepard, Chairman, American Cyanamid Co., Bound Brook, N. J.

TP-5B Design of Equipment for Corrosive Services. C. M. Shigley, Chairman, The Dow Chemical Co., Freeport, Texas.

TP-5C Sub-Surface Corrosion by Alkaline Solutions. H. W. Schmidt, Chairman, The Dow Chemical Company, 1313 Helen Street, Midland, Mich.

TP-5D Corrosion by Organic Acids and Bases in the Vapor Phase. F. L. Whitney, Monsanto Chemical Co., 1700 S. Second St., St. Louis, Mo.

TP-5E Gasket Materials for Corrosion Service. L. D. Cook, Chairman. Wyandotte Chemical Corp., Wyandotte, Mich.

TP-6 PROTECTIVE COATINGS

KENNETH TATOR, Chairman.
Consulting Engineer, Montour St.
Extension, Coraopolis, Pa.

L. L. WHITENECK, Coordinator
West Coast Division,
Board of Harbor Com.,
Long Beach, Cal.

TP-6A Organic Coatings and Linings for Resistance to Chemical Corrosion. Kenneth Tator, Chairman.

TP-6B Protective Coatings for Resistance to Atmospheric Corrosion. G. G. Sward, Chairman. National Paint, Varnish & Lacquer Ass'n., 1500 Rhode Island Ave., N.W., Washington, D. C.

TP-6C Protective Coatings for Resistance to Marine Corrosion. Raymond P. Devoluy, Chairman. G. A. Woolsey Paint & Color Co., 229 E. 42nd St., New York 17, N. Y.

TP-6D Pipe Line Coatings. (Chairman not appointed).

TP-6E Protective Coatings in Petroleum Production. (Chairman not appointed).

TP-6F Protective Coatings in the Food Industry. G. W. Seagren, Chairman. The Mellon Institute, Pittsburgh, Pa.

TP-6G Surface Preparation for Organic Coatings. A. J. Liebman, Chairman. Dravo Corp., Dravo Building, Pittsburgh 22, Pa.

TP-6H Glass Linings and Vitreous Enamel. G. H. McIntyre, Chairman. Ferro-Enamel Corp., Harvard & 56th St., Cleveland 5, Ohio.

TP-6I Metallic Coatings. (Chairman not appointed).

TP-6J Standards. G. G. Sward, Chairman.

TP-6K Chemical-Resistant Masonry Construction. Robert R. Pierce, Chairman. Pennsylvania Salt Manufacturing Co., 1000 Widener Bldg., Philadelphia, Pa.

TP-7 MATERIALS FOR USE AT HIGH TEMPERATURES

M. A. SCHEIL, Chairman.
Director Metallurgical Research,
A. O. Smith Corporation,
Milwaukee, Wisconsin

TP-8 CORROSION BY WATERS

V. V. KENDALL, Chairman.
National Tube Company, Frick
Building, Pittsburgh 30, Pennsylvania

TP-9 CORROSION INHIBITORS

A. WACHTER, Chairman.
Shell Development Company, 4560
Horton Street, Emeryville 8, California

TP-10 CORROSION FATIGUE

V. V. KENDALL, Chairman.
National Tube Company, Frick
Building, Pittsburgh 30, Pennsylvania

TP-11 IDENTIFICATION OF CORROSION PRODUCTS

C. M. SCHWARTZ, Chairman.
Battelle Memorial Institute, 505 King
Avenue, Columbus 1, Ohio

TP-12 EFFECT OF ELECTRICAL GROUNDING ON CORROSION

H. L. HAMILTON, Chairman.
Keystone Pipe Line Company,
260 South Broad Street,
Philadelphia 1, Pennsylvania

TP-13 ANNUAL LOSSES DUE TO CORROSION

F. A. ROHRMAN, Chairman
University of Colorado,
Boulder, Colo.

TP-14 INSTRUMENTS FOR CORROSION MEASUREMENTS

RAYMOND F. HADLEY, Chairman.
Susquehanna Pipe Line Co., 1608
Walnut Street, Philadelphia 3, Pa.

TP-15 CORROSION CONTROL IN THE TRANSPORTATION INDUSTRY

MERRITT A. WILLIAMSON, Chairman.
Pullman Standard Car Mfg. Co.,
79 E. Adams, Chicago, Illinois

TP-16 ELECTROLYSIS AND CORROSION OF CABLE SHEATHS

IRWIN C. DIETZE, Chairman.
Dept. of Water & Power,
City of Los Angeles, Cal.

TP-17 STANDARDIZATION OF PROCEDURE FOR MEASURING PIPE LINE COATING CONDUCTANCES

W. E. HUDDLESTON, Chairman.
Huddleston Engineering Co.,
Bartlesville, Okla.

TP-18 INTERNAL CORROSION IN STORAGE AND TRANSPORTATION OF PETROLEUM

L. G. SHARPE, Chairman.
Humble Pipe Line Co.,
Houston, Texas

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

Officers, 1950-51

President..................................VANCE N. JENKINS
Wilmington, Cal.

Vice-President ....N. E. BERRY
Evansville, Ind.

Treasurer..................................R. A. BRANNON
Houston, Texas

Executive Secretary.........................A. B. CAMPBELL
919 Milam Building
Houston 2, Texas

Directors

President

VANCE N. JENKINS.....................1950-51
Union Oil Company of Cal., Wilmington, Cal.

Vice President

N. E. BERRY.............................1950-51
Servel, Inc., Evansville, Ind.

Treasurer

R. A. BRANNON..........................1950-51
Humble Pipe Line Company, Houston, Texas

Representing Active Membership

H. D. MURRAY...........................1950-53
Cren-Ray Plastic Products Co., Midland, Texas

AARON WACHTER......................1950-53
Shell Development Co., Emeryville, Cal.

PAUL W. BACHMAN....................1949-52
Davison Chemical Corp., Baltimore, Md.

L. J. GORMAN...........................1948-51
Consolidated Edison Co. of New York, Inc., New York, N. Y.

Representing Corporate Membership

V. V. MALCOM..........................1950-53
The Philip Carey Mfg. Co., Cincinnati, Ohio

D. C. GLASS.............................1949-52
Pure Oil Company, Chicago, Ill.

E. D. VERINK, JR.......................1949-52
Aluminum Co. of America, New Kensington, Pa.

WARD R. MYERS.......................1949-51
E. I. duPont de Nemours & Co., Inc., Wilmington, Del.

D. E. STEARNS.........................1948-51
The D. E. Stearns Co., Shreveport, La.

Representing Regional Divisions

FRANK L. WHITNEY, JR..(North Central) 1950-53
Monsanto Chemical Co., St. Louis, Mo.

ROBERT H. LYNCH...........(North East) 1951
Keystone Pipe Line Co., Philadelphia, Pa.

T. F. P. KELLY...........(South Central) 1950-53
James E. Mavor Co., Houston, Texas

IRWIN C. DIETZE...............(Western) 1952
Dept. of Water & Power, City of Los Angeles, Cal.

J. T. MacKENZIE..............(South East) 1951
American Cast Iron Pipe Co., Birmingham, Ala.

Directors Ex Officio

R. B. MEARS, Past President, 1950-51
Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

E. P. NOPPEL, Chairman
Policy and Planning Committee
Ebasco Services, Inc., New York, N. Y.

MARS G. FONTANA, Chairman
Technical Practices Committee
Ohio State University, Columbus, Ohio

IVY M. PARKER, Chairman
Publication Committee
Plantation Pipe Line Co., Bremen, Ga.

L. A. BALDWIN, Chairman
Regional Management Committee
Johns-Manville Sales Corp., New York, N. Y.

The Behavior of
The Chromium Nickel Stainless Steels
In Sulfuric Acid *

By GEORGE C. KIEFER* and WILLIAM G. RENSHAW**

THE STAINLESS STEELS are characterized by their ability to form and maintain a protective surface condition in a wide variety of corrosive media. This surface condition, the nature of which has not been definitely established, is the only barrier to attack and once it is destroyed these steels exhibit the same tendency to corrode as ordinary mild steel. Under circumstances where the steel is highly resistant to attack, the metal is said to be passive, but in instances where corrosion occurs it is considered to be in the active state. While many other metals can also assume a passive condition the stability of their passive state is not nearly so great as that of the stainless steels. In most corrosive media the stainless steels either exhibit a very high degree of resistance to attack or rapidly corrode.

The passive state of these stainless steels is usually favored by an oxidizing type of environment while reducing conditions tend to promote activity. Sulfuric acid is neither a strongly oxidizing or reducing medium and has in itself no great passivating or activating abilities. The behavior of the stainless steels in sulfuric acid might therefore present an interesting study of the passive-active state of these alloys. In addition aqueous solutions having a widely varying availability of hydrogen ions can be obtained at different acid percentages.

Some metals such as iron or zinc are readily dissolved in sulfuric acid and the rate of solution is a function of the acid concentration or availability of hydrogen ions for the chemical reaction. Thus the corrosion rates for such metals are largely a function of the hydrogen ion. On the other hand, metals like copper or nickel show a fairly constant corrosion rate in most concentrations of the acid and any variations result from the availability of oxygen. With these metals the reaction involved is one of a metal oxide reacting with the acid rather than a direct combination of the metal with sulfate ion. It is possible of course in either of these cases to slow down or to accelerate the rate of solubility by controlling the hydrogen ion concentration or by providing an outside source of oxygen, but unlike the stainless steels, it is not possible to obtain complete and permanent inactivity in solutions which normally cause a high

Abstract

This article shows the corrosion rate of four commercial types of chromium nickel stainless steels and one special type in sulphuric acid of varying concentration from 0 to 95 percent, at four temperatures, 100° F (38° C), 150° F (65° C), 175° F (80° C), 200° F (93° C). The effect of additions of various sulphates and oxidizing agents to the acid on the corrosion rates is also shown. All samples were tested in an activated state and the data indicate the acid concentration and temperature, in which the metal becomes and remains passive. At temperatures about 150° F (65° C), all of the steels remain active in practically all acid concentrations and corrosion rates are high. Below this temperature, the molybdenum bearing steels, Types 316 and 317, are most resistant and increasing chromium content, Type 310, has some effect in lowering the corrosion rate. The addition of copper to the molybdenum bearing steels improves resistance to a marked degree, although these steels appear to behave similarly to copper and copper-nickel alloys in that they do not show a sharp passive-active boundary. The addition of various inorganic sulphates to sulphuric acid causes a marked lowering of corrosion rates. There is an indication that sulphates of metals below chromium in the E. M. F. series completely inhibit attack and provide a passive condition. The addition of oxidizing agents, such as nitric or chromic acid and dichromates also completely inhibits attack.

rate of solution. The inhibiting effect on the corrosion rate of stainless steel provided by the additions of several inorganic salts to the acid also would furnish interesting information on the corrosion resisting characteristics of these steels. It is the purpose of this paper to present the results of numbers of tests in order to shed some light on the behavior of stainless steels in sulfuric acid.

The data in this paper cover five different steels, four of the regular types of stainless steel and one special steel containing copper. The steels were tested in varying concentrations of sulfuric acid from 0 percent to 95 percent and at four different temperatures, 100° F (38° C), 150° F (65° C), 175° F (80° C), and 200° F (93° C). The effect of additions of various sulfates and oxidizing agents to the acid on the corrosion rates is also shown.

Analysis of Material

The samples of the four standard type stainless steels for this investigation were obtained from regular mill production and represent material commercially available. (One additional steel containing copper included in the tests will be described later.) Table I shows the analyses of the different types.

Analyses were made on the material in the form as tested.

In addition to the four compositions shown in Table I, several other heats of each of the four types were also tested under the same conditions. Very little and, in some cases, no variation in the passive-active boundary was found among the different heats of any type. These specimens were taken from bars, sheet and plate to show that the form had little to do with behavior of any certain type. The analyses shown were selected as exhibiting the typical behavior of the types which they represent.

Preparation of Samples

The material from which the samples were prepared was in the form of sheets having a cold rolled, annealed and pickled surface, equivalent to a standard commercial 2B finish. All sheared edges were machined beyond the strained area and finished with No. 120 grit emery paper.

A few preliminary tests were made, comparing the solubility of samples having completely polished surfaces with the standard 2B finish surfaces and results indicated that there were no significant differences under the testing procedure used in this investigation. All samples were therefore tested with the regular 2B finish with all edges machined and finished with No. 120 emery paper. A final degreasing and nitric-hydrofluoric acid pickling treatment was applied after all edge finishing operations were completed.

Testing Procedure

In carrying out the testing program, every precaution was taken to provide uniform conditions. One of the most important factors, particularly where sulfuric acid is concerned, is the chemical condition of the surface. Past experience in the corrosion testing of stainless steel has shown that, unless the samples are activated immediately prior to immersing in the testing medium, irregularities in results will be obtained. Even duplicate samples of the same steel, when not previously activated, frequently require widely different periods of time to become active in the testing environment and unless the tests involve relatively long periods of time, the calculated corrosion rates appear erratic. Therefore, in order to avoid such source of error, all specimens were activated immediately before testing.

There are several different methods for activating stainless steel surfaces. One of these, now rarely employed, consists of generating hydrogen in the acid by dropping small particles of zinc or aluminum adjacent to the sample. As these dissolve, the nascent hydrogen which is formed contacts the surface of the specimen and activation immediately ensues. Molecular hydrogen added from an outside source does not have the same effect.

A second method employs a pickling treatment of the specimen in nitric-hydrofluoric acid solutions.[1, 2] This produces an active surface with a negative electrode potential.

A third method and the one which was used in this work makes use of hydrochloric acid as an activating medium. The samples are immersed in a 15 percent by volume hydrochloric acid solution (approximately 5.4 percent by weight) at 150° F (65° C) for several seconds until hydrogen bubbles appear on the surface. The hydrochloric acid solution is preferred by

TABLE I

Type No.	C	Mn	P	S	Si	Cr	Ni	Mo
304	.069	.45	.020	.018	.43	18.42	9.26	....
310	.073	1.77	.017	.008	.44	24.14	20.91	....
316	.064	1.74	.022	.014	.53	17.24	13.78	2.44
317	.055	1.90	.014	.009	.50	18.50	11.69	3.45

TABLE II
Corrosion Rates at 100°F

Percent Acid	(a) As Mixed	(b) Deaerated	(c) Hydrogen Bubbled Through	(d) Air Bubbled Through
6	.0004 In/Mo	.0004 In/Mo	.0005 In/Mo	.0004 In/Mo
9	.0007	.0008	.0006	.0007
12	.0008	.0009	.0008	.0009

TABLE III
Corrosion Rates in Inches Penetration per Month at 100°F

Percent Acid By Weight	Type 304	Type 310	Type 316	Type 317
½	.0032 .0030	Nil	Nil	Nil
1	.0048 .0048	.00035 .00039	Nil	Nil
2		.00055 .00035	Nil	Nil
3	.0055 .0057	.00052 .00038	Nil	Nil
4		.0017	Nil	Nil
5	.0137 .0228	.0022 .0024	Nil	Nil
6			Nil	Nil
7			Nil	Nil
8			Nil	Nil
9			Nil	Nil
10	.0294 .0362	.0162 .0242	.0007 .0009	Nil
11			.0025 .0031	.0009 .0005
12			.0032 .0035	.0015 .0016
13			.0044 .0047	
20	.0779 .0884	.0330 .0292	.0062 .0063	.0020 .0019
40	.0746 .0675	.0661 .0743	.0690 .0686	.0169 .0198
60	.1213 .1092	.1028 .1034	.2367 .2294	.2305 .2541
80	.0612 .0616	.0276 .0393	.0225 .0246	.0485 .0480
95	.0003 .0004	.0003 .0005	Nil	Nil

TABLE IV
Corrosion Rates in Inches Penetration per Month at 150°F

Percent Acid By Weight	Type 304	Type 310	Type 316	Type 317
½	.0183 .0189	Nil	Nil	Nil
1	.0177 .0193	.0035 .0038	Nil	Nil
2		.0048 .0057	Nil	Nil
3	.0326 .0323	.0057 .0059	.00068 .00069	Nil
4		.0056 .0062	.0012 .0010	Nil
5	.0939 .0887	.0072 .0070	.0032 .0028	.00039 .00045
10	.1475 .1587	.1274 .1310	.0062 .0073	.0065 .0066
20	.4763 .4869	.2170 .2134	.0156 .0162	.0168 .0163
40	1.10 1.03	.3822 .3784	.5390 .5330	.2255 .2332
60	1.46 1.43	.7079 .7304	1.300 1.340	.9284 .8740
80	.1054 .1043	.1520 .1477	.0485 .0470	.0909 .0959
95	.0117 .0136	.0209 .0181	.0052 .0047	.0072 .0069

the authors over nitric-hydrofluoric acid solutions as an activating medium because it requires a much shorter time to produce activity and is a more certain procedure.

The standard procedure for testing, therefore, consisted of taking the samples as prepared in the preceding section, weighing, immersing in a 15 percent by volume hydrochloric acid at 150° F (65° C) until the surface was covered with hydrogen bubbles, washing thoroughly in water and then without drying, immersing in the testing solution. The small weight loss resulting from the hydrochloric acid activation was ignored because preliminary tests showed that the amount of metal dissolved was less than one milligram for the entire sample. In a number of the sulfuric acid solutions where the metal became passive during the test, an additional activating procedure was used to check the efficiency of the hydrochloric acid treatment. Very small particles of powdered zinc were dropped in the solution adjacent to the metal, but in no case did reactivation occur.

Tests were conducted in duplicate for a two-hour period in beakers submerged in a water bath to con-

trol the temperature accurately. A longer period of testing was believed unnecessary as the primary purpose of the investigation was to determine the passive-active boundary. Where the corrosion rates are high, their magnitude is of little practical significance, and variations from heat to heat are found depending upon melting practice and processing. Further, it is believed that if the samples become passive after an original activating treatment, then a two-hour test period should be long enough to observe any marked changes.

Chemically pure sulfuric acid and distilled water were used for all tests. In order to determine what effect dissolved gases in solution had upon corrosion rates, preliminary tests were conducted. Solutions of three different acid concentrations were selected in the lower range where the stainless steel employed might be either active or passive and the following conditions were included: a) as mixed, b) deaerated, c) hydrogen bubbled through solution during entire test period, and d) air bubbling through the solution during entire test period. Table II shows the corrosion rates for Type 316 in all solutions. Because little variation in the corrosion rates were found as a result of the presence of gases in the solution, all tests were carried out in the acids as mixed.

Results of Tests

The corrosion rates for the various types of stainless steels tested are shown graphically in Figures 1, 2, 3, and 4 and the individual rates are compiled in Tables 3, 4, 5 and 6. The graphs were broken in order to present a better picture of the behavior in the lower acid concentrations.

It can be seen that the molybdenum-bearing stainless steels, Types 316 and 317, show the best resistance to sulfuric acid. They become passive in concentrations up to 9% and 11% at 100° F (38° C), 3% and 5% acid at 150° F (65° C), and 2% and 4% acid at 175° F (80° C), respectively. At 200° F (93° C) the passive state is limited to about 0.5% acid for Type 316 and 1% for Type 317. The regular 18-8 stainless steel type remains active in practically all

TABLE V
Corrosion Rates in Inches Penetration per Month at 175°F

Percent Acid By Weight	Type 304	Type 310	Type 316	Type 317
½	.0309 .0366	.0038 .0040	Nil	Nil
1	.0287 .0355	.0069 .0068	Nil	Nil
2		.0084 .0085	.00039 .00042	Nil
3	.0442 .0437	.0094 .0097	.0034 .0033	.00052 .00045
4		.0108 .0097	.0048 .0038	.00052 .00045
5	.1286 .1448	.0137 .0133	.0069 .0074	.0075 .0076
10	.3779 .3724	.2210 .2213	.0127 .0132	.0159 .0169
20	.9042 .8707	.4440 .4565	.0615 .0792	.0489 .0474
40	2.82 2.86	.7293 .8833	1.510 1.582	.8068 .8514
60	3.49 3.51	1.22 1.18	2.849 2.932	2.318 2.327
80	.1878 .1570	.5307 .4950	.0968 .1034	.2938 .2671
95	.0115 .0115	.0212 .0218	.0065 .0073	.0210 .0225

TABLE VI
Corrosion Rates in Inches Penetration per Month at 200°F

Percent Acid By Weight	Type 304	Type 310	Type 316	Type 317
½	.0638 .0678	.0041 .0042	.00016 .00048	Nil
1	.0627 .0684	.0065 .0067	.0046 .0046	Nil
2		.0092 .0089	.0067 .0067	.0049 .0050
3	.1112 .1051	.0108 .0101	.0075 .0081	.0098 .0098
4		.0130 .0134	.0083 .0083	.0121 .0127
5	.4504 .4609	.0143 .0125	.0120 .0113	.0199 .0188
10	.4911 .6644	.2314 .2410	.0189 .0173	.0466 .0446
20	1.75 1.78	1.11 1.03	.1475 .1479	.0886 .0886
40	6.69 7.01	1.96 2.05	3.053 2.992	2.375 2.326
60	8.67 8.50	2.48 2.41	5.106 5.219	4.605 4.581
80	.6897 .5770	.8140 .8761	.3311 .3399	.5055 .5022
95	.0149 .0145	.0296 .0284	.0307 .0258	.0460 .0461
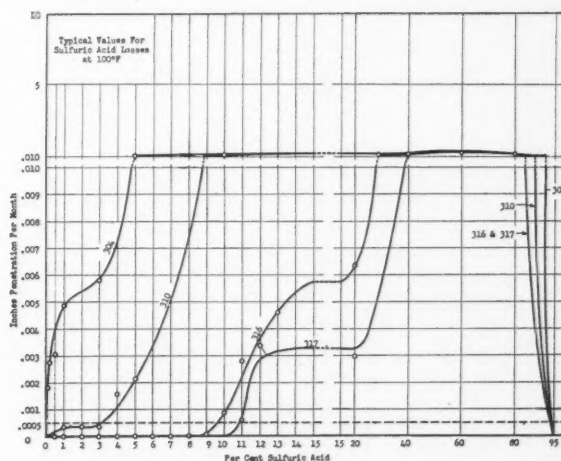
Figure 1

acid concentrations even at 100° F (38° C). It will be noted the 25% chromium 20% nickel steel, Type 310 exhibits somewhat better resistance than Type 304 but not quite as good as the molybdenum Types 316 and 317.
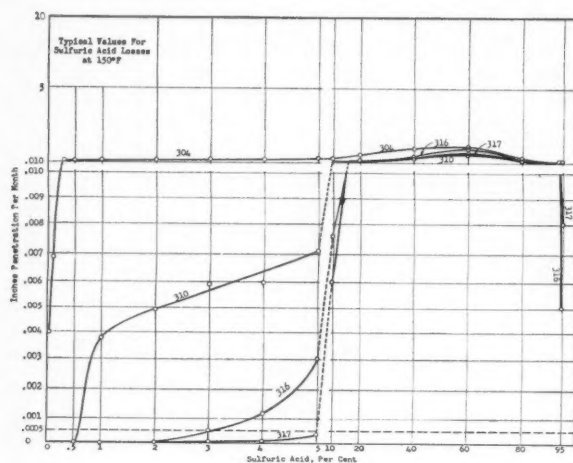
Figure 2
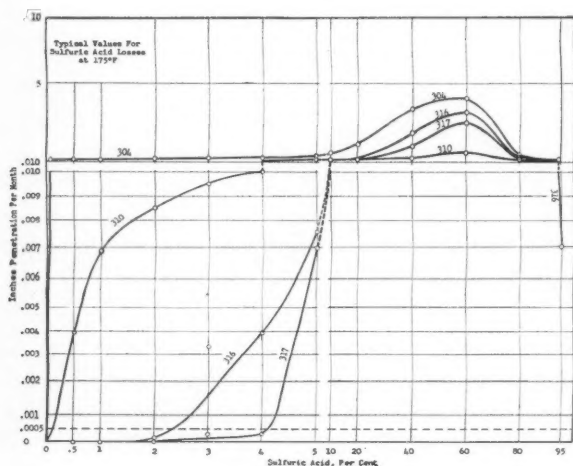
Figure 3
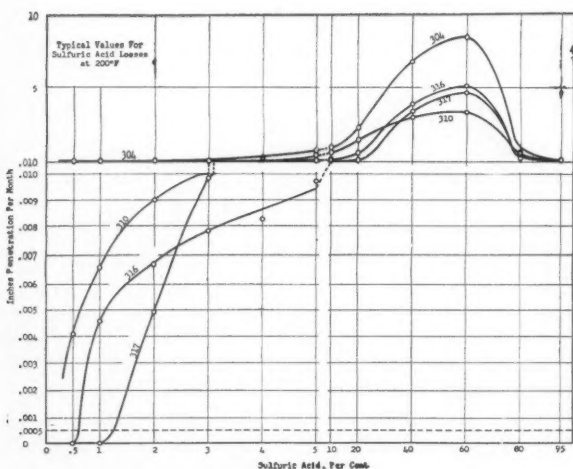
Figure 4

A dotted line has been placed on each graph indicating a corrosion rate of .0005-inch penetration per month. This figure represents an arbitrary value selected many years ago as a maximum corrosion rate below which stainless steel could be considered suitable for a given application. It is interesting to note that at or below this line changes from the passive to the active state become evident. In nearly every case, the curve remains flat below this line, but shows a very sharp rise as soon as this value of .0005-inch penetration per month is attained and exceeded. In the case of stainless steel it would appear that the sulfuric acid corrosion rates higher than .0005-inch penetration per month indicate an active state for the metal.

According to data shown in the International Nickel Company Bulletin "T3," a maximum hydrogen ion concentration of 1.95 grams per liter occurs at about 30 percent by weight sulfuric acid solution. However, stainless steels show their highest corrosion rates at about 60 percent by weight sulfuric acid, while iron shows a maximum in the neighborhood of 47 percent.[3] While this would indicate that the hydrogen ion concentration might be still higher at acid concentrations above 30 percent, other factors probably are involved; namely, some complex reactions which are not merely the replacement of hydrogen ion by metal such as found at 30 percent acid or lower, but include chemical action within the acid itself. In addition, the effective hydrogen ion concentration can be considerably different from the stoichiometric concentration due to possible physical influences such as hydration of the ions or repulsion between large hydrated ions.

However, regardless of the maximum corrosion rates shown for the various stainless steels, it is interesting to note their behavior in the lower acid concentrations where they are almost completely unreactive. For example, Types 316 and 317 are passive in acid concentrations as high as 9 percent and 11 percent, respectively, at 100° F (38° C). At these acid concentrations there is a wealth of hydrogen ions available, yet these steels are practically unaffected. It is probable that at these lower acid concentrations, oxidizing conditions of sufficient magnitude are present to promote a passive state even though the acid is highly ionized at these concentrations. Although sulfuric acid is not a powerful oxidizing agent in the same sense as nitric or perchloric acid, nevertheless at a 1.0 molal concentration (about 8.9 percent by weight sulfuric acid) at 77° F (25° C) the oxidation-reduction potential for the reaction shown below indicates that sulfuric acid is a mild oxidizing agent:[4]

$$H_2SO_3 + H_2O \rightleftharpoons SO_4^= + 4H^+ + 2e \boxed{Z} + .20 \text{ volts}$$
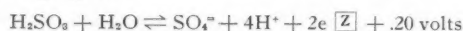
In accordance with the convention employed by the Electrochemical Society and the National Bureau of Standards, the potential of this reaction is shown with a positive sign.

While this oxidizing ability is only slight, it may be sufficient in certain instances to maintain a pas-

sive state depending upon the potential of the electrode which is immersed in the solution:

Assuming a hypothetical electrode:

$$\text{Stainless Steel} = \text{Stainless Ion}^x + xe$$

it would be expected that when the resulting potential is negative (above hydrogen) the steel would be active. If, however, the potential is positive (below hydrogen) then the steel would be unreactive.

In fairly dilute solutions of sulfuric acid the hydrogen ions tend to produce activation which is working in direct opposition to the slightly oxidizing effect of sulfate ion. While no graphical representation or numerical value can be shown for these two effects against each other, it is probable that the summation of these two would still permit activation at the higher percentages but not to the same extent as the hydrogen ion alone would exert. When the acid concentration decreases below 30 percent the hydrogen ion concentration decreases, and the oxidation-reduction potential is also changing but at a different rate. Thus, at 100° F (38° C) in the case of Type 316 at 9 percent acid or lower, the activating effect of the hydrogen ions present is sufficiently moderated by the slightly oxidizing potential of the sulfate ion so that the passive electrode potential of the Type 316 cannot be overcome.

In the passive state, different types of stainless steel have slightly different EMF values. In most cases Types 316 and 317 have the most positive values and this may account for their wider range of passivity. It is also known that these two types have a positive potential under mildly oxidizing conditions whereas the other types not containing molybdenum require much stronger oxidizing environments to maintain a positive potential. Increasing chromium contents also widen the range of passivity but not to the same extent as molybdenum.

The corrosion rate for all the steels is high once passivity is destroyed. Type 304 is quite soluble in all acid concentrations and at all temperatures except in the 95 percent acid at 100° F (38° C). Type 310 with its higher chrominum and nickel content shows somewhat better resistance in the very low concentrations at 100° F (38 C°), but the passive range is quite limited.

The behavior of the stainless steels in the concentrated or 95 percent acid is very similar to that of ordinary mild steel. The excellent resistance of iron and steel in concentrated sulfuric acid has been discussed by many investigators. At such high concentrations, ionization of the acid is extremely low and the corrosion products that do form on the surface of the iron and steel are practically insoluble in the acid, thereby setting up a barrier against further attack. In these high concentrations, more strongly oxidizing conditions exist as shown by the sharp rise in the corrosion rate of copper or nickel in the more concentrated solutions.

With the stainless steels as shown in Table VII, no losses are found at 100° F (38° C) in 95 percent sulfuric acid. Any slight dilution causes a marked rise in the corrosion rates for all four types. Although not shown in the table, any rise in temperature above

100° F (38° C) even at 95 percent sulfuric acid also causes an increase in the corrosion rates.

The Effect of Sulfate Additions

Some information on the inhibiting effect of metallic sulfates on the solubility of stainless steel in sulfuric has been available. For example, the use of sulfuric acid—copper sulfate solutions for testing stainless steel, the wide application of these steels for copper and brass pickling equipment and their behavior in ammonium sulfate saturators were indicative of the possibilities of sulfates as inhibitors. There are very little data, however, on the effect of many other sulfates. It was believed that a study including some of the other sulfates might shed some light on the nature of the passive condition of these steels.

The effect of the addition of seven different sulfates to two different concentrations of sulfuric acid was investigated. Only two different types of stainless steel were employed. Varying amounts of ammonium, sodium, manganese (manganous), iron (ferrous), nickel (nickelous), tin (stannous), and copper (cupric) sulfates were added to 5 percent and 30 per-

TABLE VII
Losses in Inches Penetration per Month
Sulfuric Acid Losses at 100°F in 85% to 95% Concentrations

	Type 304	Type 310	Type 316	Type 317
95 percent	Nil	Nil	Nil	Nil
94 percent	.0070	.0034	.0032	.0032
93 percent	.0084	.0039	.0032	.0031
92 percent	.0085	.0043	.0035	.0048
91 percent	.0088	.0060	.0042	.0056
90 percent	.0098	.0079	.0039	.0083
85 percent	....	....	.0041	.0124
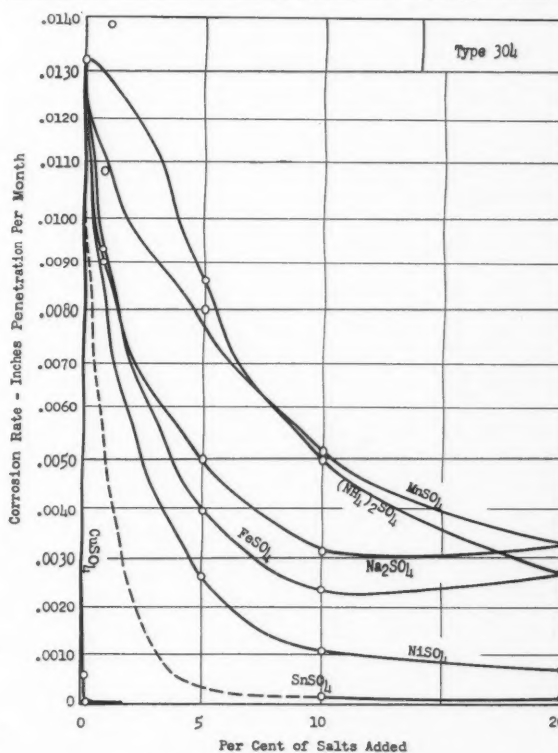
Figure 5—5 percent sulfuric acid at 100° F.

cent sulfuric acid. Types 304 and 316 were tested in these solutions. It will be noted that with the exception of copper sulfate, the other sulfates are either monovalent or are in their lower valence states.

The results of tests are shown in Figures 5 to 10 inclusive. A study of the data will show that certain significant findings are apparent. First, the presence of any of the sulfates materially lowers the corrosion rates of both Types 304 and 316 in 5 percent sulfuric acid. As the temperature increases, the effect becomes less pronounced particularly with Type 304 except when copper or tin (stannous) sulfate is present, as indicated by Figure 5 at 100° F (38° C), Figure 6 at 150° F (55° C), Figure 7 at 175° F (80° C) and Figure 8 at 200° F (93° C). The effect of stannous sulfate at 150° F and 175° F was not determined, but it can be assumed that it would lower the corrosion rates in a manner similar to that found at 100° F and 200° F. In 30 percent sulfuric acid, the influence of sulfate upon the corrosion rate is not nearly so strong as in 5 percent acid, except for copper and tin sulfates in the case of Type 304 and copper, tin and nickel sulfates with Type 316.

The most significant indication in the data is the importance of the metal ion present. It will be noted that the sulfates of metals above nickel in the EMF series vary but slightly in their inhibiting effect. None of these sulfates provides complete inhibition, i.e., a corrosion rate under .0005 IPM. Nickel sulfate is somewhat more effective than the sulfates of the more negative metals which stand above it in the series, and lowers the corrosion rate to a greater degree. In only one case, however, namely Type 316 in 5 percent sulfuric acid at 150° F, does it provide a corrosion rate less than .0005 IPM. Tin (stannous) sulfate does produce corrosion rates under .0005 IPM, particularly in the case of Type 316 and also in a number of instances with Type 304. Copper sulfate

is, of c...
all tem...

Whil...
must b...
ficient...
trends...
metals...
passivi...
merely...
difficul...
and nic...
lar effe...
increas...
acid at...

Stan...
provic...
200° F...
that th...
There...
copper...
copper...
maintai...
parison...
others...
and W...
sulfate...
inhibit...

In a...
additio...
oxidizi...
um dic...
of add...
5 perc...
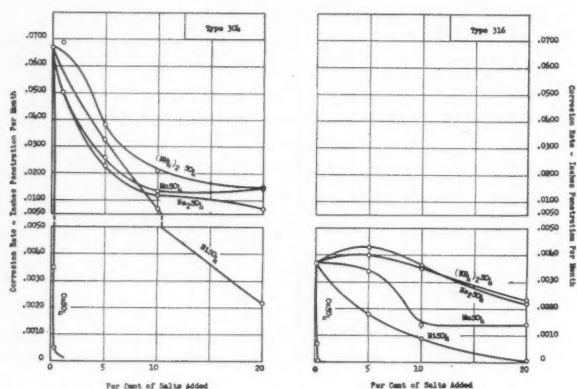
Figure 6—5 percent sulfuric acid at 150° F.
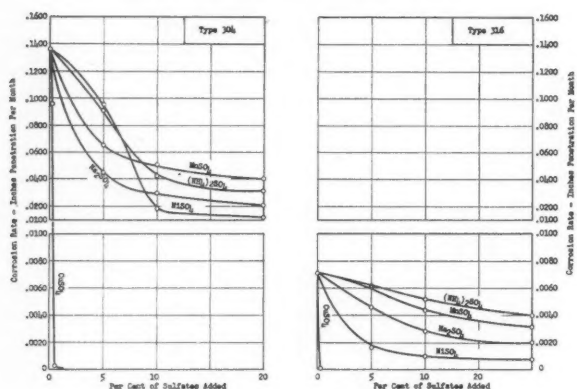
Figure 7—5 percent sulfuric acid at 175° F.
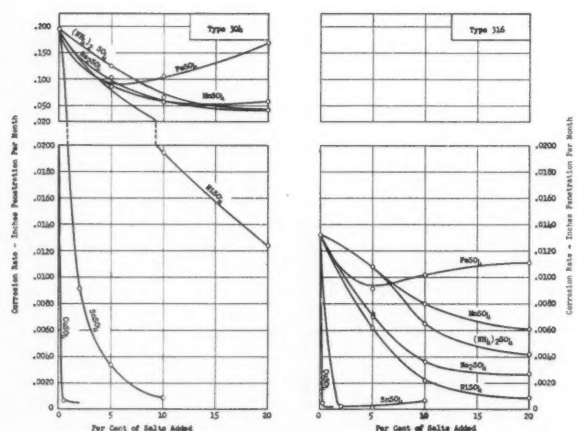
Figure 8—5 percent sulfuric acid at 200° F.
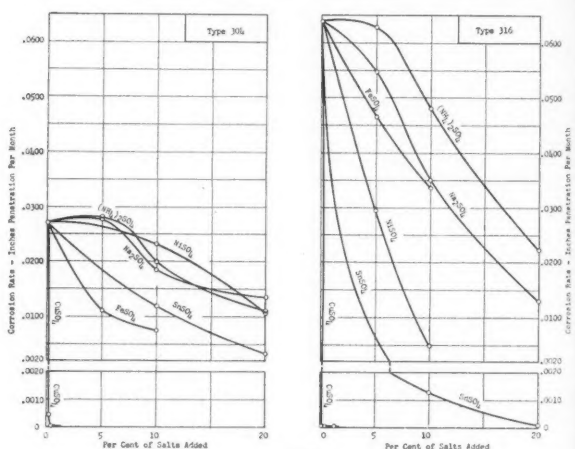
Figure 9—30 percent sulfuric acid at 100° F.
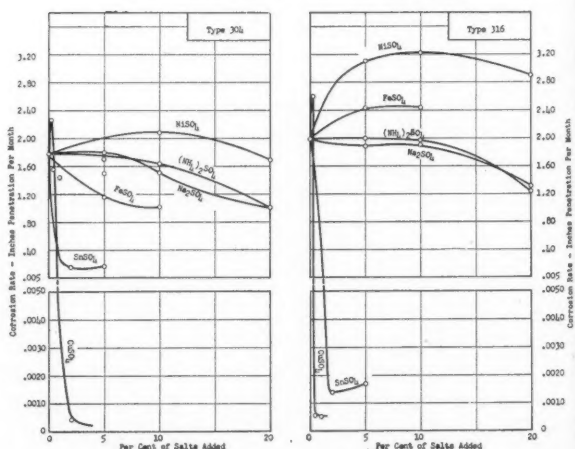
Figure 10—30 percent sulfuric acid at 200° F.

is, of course, effective in all concentrations and at all temperatures.

While there are many voids in the data which must be filled to obtain a more positive picture, sufficient information has been provided to indicate trends. A study of the data shows that sulfates of metals above iron have little effect in producing passivity of the stainless steels and their function is merely one of retarding ionization or making it more difficult for ion movement in solution. Iron (ferrous) and nickel (nickelous) sulfate may also have a similar effect, but it is difficult to explain the unexpected increase of the corrosion rate in 30 percent sulfuric acid at 200° F. when they are added.

Stannous sulfate approaches copper sulfate in providing passivity, but in 30 percent acid at 200° F. it does not reduce corrosion to the extent that the metals could be considered passive. There is one difference, namely, the valence state of copper which may account for the marked effect of copper sulfate, but unfortunately, it is impossible to maintain cuprous sulfate as such, in solution. A comparison of the effectiveness of this metal ion with others is clouded by its higher valence state. McKay and Worthington,[5] however, show that mercurous sulfate is practically as effective as copper sulfate in inhibiting attack.

Effect of Oxidizing Agents

In addition to investigating the effect of sulfate additions, tests were carried out with three different oxidizing agents: nitric acid, chromic acid and sodium dichromate. Figures 11, 12 and 13 show the effect of additions of these agents on the corrosion rate in 5 percent and 30 percent sulfuric acid. In all cases,

these oxidizing agents provided complete passivity with both Types 304 and 316. The amount of each agent varies slightly and only relatively small amounts of each are required. Chromic acid is most effective.

Discussion

It is difficult to offer any conclusive explanation of the mechanism of inhibition or passivation provided by sulfates or oxidizing agents.

In the case of sulfates (ammonium, sodium, manganous, and ferrous sulfates), which only lower the corrosion rate to a limited degree, it can be reasoned that their presence merely "loads" the solution, thus retarding ionic movement and that their inhibiting effect is proportional to the corrosion rate of the steel in the straight acid solution. As the corrosion rates of stainless steel in the active state are quite high, considerable variation from melt to melt and from type to type may be expected. The presence of any of these sulfates in the acid solution would therefore lower the corrosion rate proportionately. The fact that these sulfates have very little inhibiting effect in solutions at the higher temperatures appears to bear out this conclusion.

Nickel and tin (stannous) sulfates are more effective inhibitors than the sulfates mentioned above. In fact, in a number of cases, a passivating effect is indi-

Figure 12—5 percent sulfuric acid at 200° F.

Figure 11—5 percent sulfuric acid at 100° F.
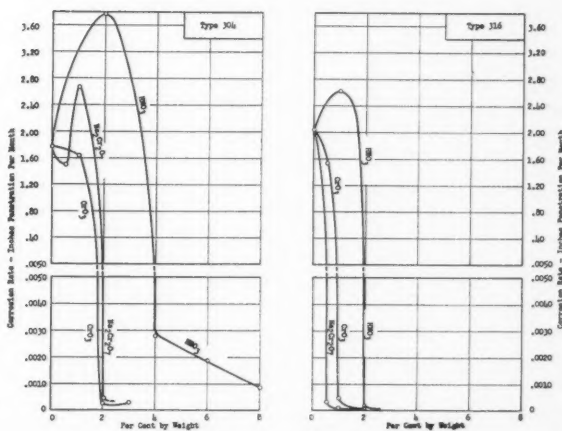
Figure 13—30 percent sulfuric acid at 200° F.

cated. It will be noted that nickel sulfate, except in 30 percent acid at 200° F, causes a more marked lowering of the corrosion rate than the sulfates of metals having a more negative EMF, and in the case of Type 316, corrosion rates approaching .0005 IPM are obtained. This indicates that the effect of nickel sulfate is more than a retarding of ionic movement or a slowing-down of the chemical reaction and, in the case of Type 316, actually has a passivating effect. It can be seen from Figure 11 (30 percent at 200° F) that nickel sulfate has a similar characteristic of most so-called passivating agents, in that certain combinations of acid and sulfate produce a marked increase in corrosion rate.

The effect of tin (stannous) sulfate is more marked than nickel sulfate in providing a passive condition. The presence of tin sulfate causes the lowering of the corrosion rate to an extent, that in many cases, is equivalent to that of a passive state. It loses some of its potency in 30 percent sulfuric acid but the solubility of the salt in this acid concentration in any moderate amounts is doubtful because some precipitation occurred even when 10 percent was added.

Copper sulfate is quite effective in providnig passivity in all acid concentrations and temperatures.

It will be noted that the sulfates of iron, nickel and tin are in the lower valence state. McKay and Worthington[5] show data indicating that mercurous and silver sulfates are about as effective as copper sulfate. Copper sulfate is stable only in the bivalent state. This precludes any generalization, in these cases, as to the effect of oxidation-reduction potentials on the passivation of the metal. There is some strong evidence that the metal ion is of importance as it can be seen that the effectiveness of the sulfate is related to the position of the corresponding metal in the EMF series of elements. It would appear then that the oxide film theory of passivation is not adequate to explain these phenomena and that the electron configuration theory is more applicable. However,
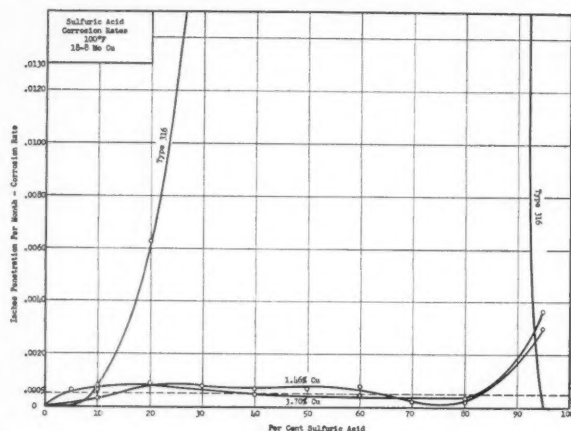
Figure 14
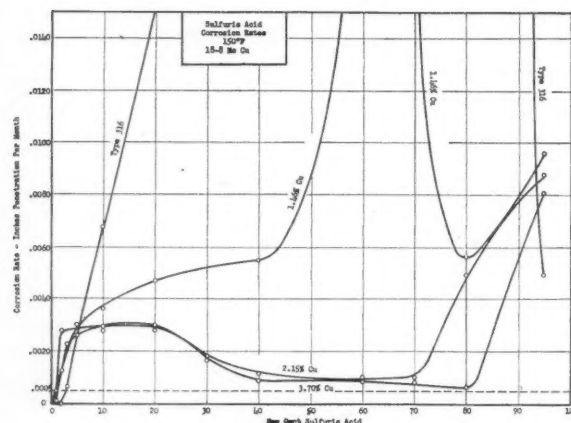
Figure 15
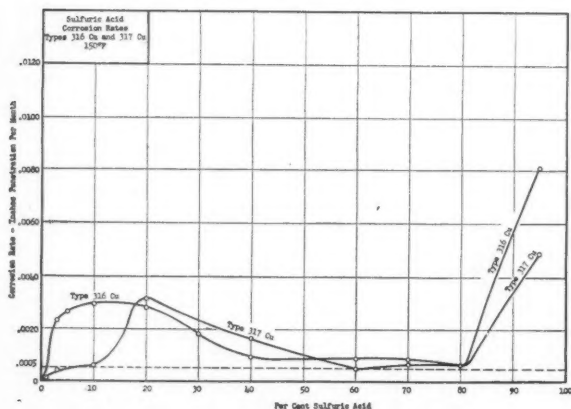
Figure 16
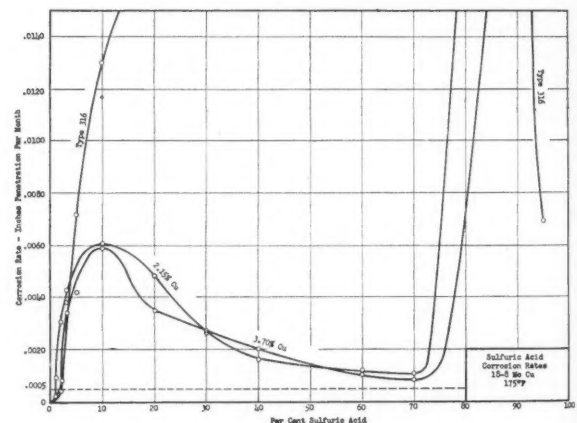
Figure 15-A
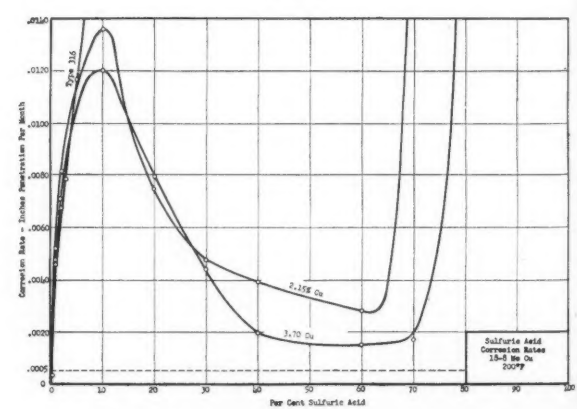
Figure 17

while time did not permit additional tests, it is known from experience in pickling stainless steel, that ferric sulfate is a much more effective inhibitor than ferrous sulfate. It is also known that the inhibiting effect of chromous or chromic salts is not as effective as chromates. Until better understanding is reached as to the nature of solutions and the structure of metals, it is probable that no one theory will clearly account for the behavior of metals in corrosive media.

18-8 Mo Steels Containing Copper

As the preceding data indicated that the copper ion in solution had a very marked inhibiting effect, it was reasoned that perhaps a similar effect could be obtained by adding copper to the steel. To this end, a limited number of steels containing both molybdenum and copper were investigated. Table VIII gives the analyses of the steels tested.

Figures 14 to 17 inclusive and Tables IX to XII inclusive show the corrosion rates of these steels in the various acid concentrations and at the temperatures involved.

It will be noted that the addition of copper to the molybdenum bearing stainless steels causes a marked lowering of the corrosion rates.

At 100° F (38° C) for example, all of the steels containing 1.5 percent copper or more show excellent resistance to attack in all acid concentrations up to 80 percent as shown by Figure 14 and inspection of Table IX.

Figure 15 at 150° F (65° C) indicates that steels containing more than 2 percent copper show good resistance to attack up to about 80 percent acid concentrations. Figure 15-A, also at 150° F, which compares Types 316 and 317 both with about 3.7 percent copper does show the influence of the higher molyb-

denum content in the dilute acid range below 20 percent.

At 175° F (80° C), Figure 16, the steels containing more than 2 percent copper show much lower corrosion rates than the regular Types 316 and 317, but these are considerably higher than .005 IPM.

When the temperature is increased to 200° F (93° C), the corrosion rates shown in Figure 17 are quite high in all acid concentrations for the steels containing more than 2 percent copper.

The addition of copper to the molybdenum-bearing stainless steels causes some very marked changes in their behavior in sulfuric acid. It lowers the corrosion rate in acid concentrations up to 80 percent at temperatures up to 150° F (65° C) to a very marked degree. These low rates under such conditions are for the most part satisfactory for commercial applications (Figures 14 and 15).

TABLE X—18-8 Mo with Copper Added
Sulfuric Acid Corrosion Rates in Inches Penetration per Month
150°F

Percent H₂SO₄	Type 316	Type 316 + 146% Cu	Type 316 + 1.75% Cu	Type 316 + 2.15% Cu	Type 316 + 3.70% Cu	Type 317 + 3.74% Cu
1	Nil	....	....	.00045 .00055	.00016 .00013	.00023 .00013
2	Nil	.0013 .0015	.0026 .0024	.0028 .0028	Nil	Nil
3	.00068 .00069	....	....	....	.0023 .0023	.00038 .00048
5	.0032 .0028	....	....	.0031 .0029	.0028 .0025	Nil
10	.0062 .0073	.0037 .0035	.0042 .0039	.0030 .0026	.0033 .0026	.00019 0012
20	.0156 .0162	.0049 .0045	.0063 .0056	.0030 .0030	.0027 .0029	.0030 .0033
30	.4048 .3866	....	....	.0017 .0017	.0018 .0018	.0020 .0016
40	.5390 .5330	.0050 .0061	.0063 .0128	.0012 .0012	.00097 .00094	.0018 .0015
60	1.30 1.34	.0474 .0514	.0535 .0503	.0010 .0011	.00078 .0010	.00058 .00049
70	.2750 .2721	....	....	.0010 .0011	.00081 .00087	.00071 .00071
80	.0485 .0470	.0055 .0058	.0083 .0068	.0041 .0058	.00042 .00084	.00055 .00065
95	.0052 .0047	.0096 .0096	.0090 .0077	.0096 .0080	.0076 .0086	.0048 .0050

TABLE XI—18-8 Mo with Copper Added
Sulfuric Acid Corrosion Rates in Inches Penetration per Month
175°F

Percent H₂SO₄	Type 316	Type 316 + 146% Cu	Type 316 + 1.75% Cu	Type 316 + 2.15% Cu	Type 316 + 3.70% Cu	Type 317 + 3.74% Cu
1	Nil	.00091 .0014	.0045 .0026	.0015 .00026	.00087 .0010	.00019 .00026
2	.00039 .00042	....	....	.0029 .0031	.00081 .00094	.00049 .00055
3	.0034 .0033	.0046 .0047	.0058 .0058	.0038 .0047	.0038 .0038	.0018 .0012
5	.0069 .0074	.0055 .0059	.0062 .0058	....	.0043 .0040	.00097 .0026
10	.0127 .0132	.0069 .0067	.0093 .0075	.0060 .0061	.0059 .0060	.0057 .0051
20	.0615 .0792	.0027 .0028	.0048 .0043	.0047 .0049	.0036 .0033	.0091 .0084
30	.6820 .8674	....	....	.0024 .0027	.0024 .0030	.0031 .0028
40	1.51 1.58	.0050 .0066	.0159 .0152	.0017 .0015	.0021 .0019	.0015 .0017
50	2.58 2.63	....	....	....	....	....
60	2.85 2.93	.0961 .0924	.0999 .1012	.0011 .0013	.0010 .0011	.0014 .0015
70	.5627 .5649	....	....	.0010 .0011	.00077 .00093	.00097 .00087
80	.0968 .1034	.0347 .0328	.0120 .0131	.0171 .0189	.0194 .0122	.0083 .0089
95	.0065 .0073	.0214 .0219	.0173 .0174	.0205 .0227	.0179 .0176	.0127 .0117

TABLE VIII

	C	Mn	P	S	Si	Cr	Ni	Mo	Cu
Type 316 (BP5).....	.07	1.04	.018	.016	.51	17.10	11.86	2.82	1.46
Type 316 (BP43).....	.07	1.02	.017	.009	.46	17.37	10.94	2.44	1.75
Type 316 (BQ33).....	.06	.90	.021	.020	.54	17.83	12.80	2.64	2.15
Type 316 (BQ95).....	.06	1.09	.018	.024	.59	17.92	13.13	2.73	3.70
Type 317 (BQ96).....	.05	.90	.018	.016	.47	19.43	13.02	3.67	3.74

TABLE IX—18-8 Mo with Copper Added
Sulfuric Acid Corrosion Rates in Inches Penetration per Month
100°F

Percent H₂SO₄	Type 316	Type 316 + 146% Cu	Type 316 + 1.75% Cu	Type 316 + 2.15% Cu	Type 316 + 3.70% Cu	Type 317 + 3.74% Cu
2	Nil	......	....	Nil	....	....
5	Nil	....	....	Nil	.00065 .00052	.00032 Nil
10	.0007 .0009	.00023 .00042	.00019 .00023	.00052 .00023	.00062 .00071	.00039 Nil
20	.0062 .0063	.00087 .00084	.00047 .00091	.00075 .00081	.0010 .00075	.00039 Nil
30	.0258 .0251	.00058 .00091	.00071 .00064	....	....	....
40	.0690 .0686	.00074 .00064	.00068 .00068	.00039 .00049	.00049 .00049	.00042 .00045
50	.1230 .1282	.00081 .00058	.00051 .0010	....	....	....
60	.2367 .2294	.00055 .0010	.00042 .00058	.00045 .00062	.00045 .00045	.00039 .00039
70	.0901 .0891	.00016 .00019	Nil	....	....	....
80	.0225 .0246	.00016 .00029	Nil	Nil	.00036 .00052	.00045 .00023
95	.0003 .0004	.0030	.0021 .0010	.0032 .0031	.0034 .0039	.0027 .0028

TABLE XII—18-8 Mo with Copper Added
Sulfuric Acid Corrosion Rates in Inches Penetration per Month
200°F

Percent H₂SO₄	Type 316	Type 316 + 146% Cu	Type 316 + 1.75% Cu	Type 316 + 2.15% Cu	Type 316 + 3.70% Cu	Type 317 + 3.74% Cu
½	.00016 .00048	.00091 .00087	.0012 .00082	....	....	....
1	.0046 .0046	.0015 .0038	.0038 .0038	.0043 .0052	.0053 .0050	.00029 .00036
2	.0067 .0067	.0083 .0079	.0080 .0072	.0081 .0081	.0072 .0069	.00052 .00039
3	.0075 .0081	.0108 .0108	.0133 .0123	....	....	.0051 .0041
5	.0120 .0113	.0101 .0108	.0133 .0128	....	....	.0102 .0110
10	.0189 .0173	.0091 .0108	.0202 .0181	.0130 .0141	.0106 .0133	.0167 .0159
20	.1475 .1479	.0225 .0196	.0307 .0311	.0076 .0073	.0081 .0077	.0260 .0237
30	2.41 2.39	....	....	.0050 .0045	.0045 .0043	.0050 .0055
40	3.05 2.99	.0429 .0499	.0521 .0509	.0037 .0042	.0019 .0020	.0045 .0035
60	5.11 5.22	.1321 .1308	.1578 .1198	.0030 .0026	.0014 .0016	.0018 .0019
70	.9323 .9542	.0490 .0689	.0451 .0520	.0193 .0233	.0017 .0017	.0019 .0020
80	.3311 .3399	.0464 .0955	.0423 .0468	.0336 .0383	.0177 .0181	.0175 .0173
95	.0307 .0258	.0298 .0333	.0459 .0352	.0298 .0288	.0269 .0260	.0238 .0252

The behavior of these copper-bearing steels is quite similar to copper itself in that the corrosion rates in acid concentrations above 80 percent are quite high. The data show that at 95 percent acid concentration these rates for the copper-bearing steels are considerably higher than the regular Type 316 without copper at practically all temperatures.

In the lower acid concentrations, under 10 percent, the presence of copper narrows the passive range of the steel. A study of Figure 15-A indicates that this may be a matter of the chromium and/or molybdenum content because Type 317 with its higher chromium and molybdenum contents has a wider range of passivity than Type 316 with an equivalent copper content. Generally speaking, however, it would appear that the corrosion rate of these copper-bearing steels is a function of the availability of hydrogen ions and/or the availability of oxygen. High rates are found at the higher temperatures in the acid concentration range between 5 percent and 30 percent where the availability of hydrogen ions is greatest and above 80 percent where the availability of oxygen is greatest.

It is interesting to note that copper additions in excess of 2 percent show little advantage of any further improvement in corrosion rates. A steel containing 1.46 percent copper shows excellent resistance at 100° F (38° C) but at 150° F (65° C) its corrosion rates are quite high. Increasing the copper content to 2.15 percent causes a marked improvement at the higher temperature. A further increase to 3.70 percent copper, which approaches the maximum solubility of copper in iron, does not provide much improvement over the steel containing 2.15 percent copper (Figure 15).

Summary

In pure sulfuric acid solutions the passive-active boundaries for four different types of stainless steel were determined. The passive range for these steels varies between 0 and 11 percent at 100° F depending upon the type of steel. Steels containing molybdenum have the widest range of passivity. All of the stainless steels tested were passive in 95 percent acid at 100° F. At temperatures above 150° F all these steels generally show very high corrosion rates in all acid concentrations.

The addition of metallic sulfates and oxidizing agents to the acid lowers the corrosion rates of all the steels tested. The inhibiting effect is related to the metal ion, varying in effectiveness with the electrode potential of the metal involved. Thus copper sulfate is most effective, followed in order by tin and nickel.

Molybdenum-bearing stainless steels containing copper show marked improvement in resistance to sulfuric acid. Steels containing over 2 percent copper are very resistant in all acid concentrations up to 80 percent at 100° F (38° C). At higher temperatures, these steels also show low corrosion rates in certain ranges of acid concentration.

References

1. G. C. Kiefer, "The Passivation and Coloring of Stainless Steels," before 22nd Annual ASM Convention, October 21-25, 1940. Published by ASM in "Surface Treatment of Metals," 1941, Pages 20-32.
2. R. O. Bayer and E. A. Kachick, "A Method of Activating Stainless Steel Specimens Prior to Corrosion Tests," *Corrosion*, **5**, 308-310 (1949).
3. H. H. Uhlig, Corrosion Handbook, p. 133 (1948).
4. Latimer and Hildebrand, Reference Book of Inorganic Chemistry, Page 243, Revised Edition (1940).
5. McKay and Worthington, Corrosion Resistance of Metals and Alloys, Page 302 (1936).

Training Program for Corrosion Technicians*

By JAMES R. COWLES

FOUR YEARS AGO when Oklahoma Natural Gas Company began to install anodes it was found that one or two engineers could not be always at the right place at the right time if many small jobs were to be done. At the same time the distribution superintendent in Shawnee decided there was nothing about burying anodes that his local personnel could not manage. It was agreed therefore that Shawnee District should be allowed to purchase $250.00 worth of meters and equipment and install its own anodes with broad guidance from the general engineering department. By August, 1948, the district had installed 109 anodes with only nine "duds" or inactive anodes. The 100 anodes which were effective protected $4800 worth of old coated pipe on which leakage was getting out of hand and $21,580 worth of newly laid pipe. Actual charges on the books were $2564 not counting the $250.00 for instruments. It was estimated that $1054 of these outlays should be charged to the education of personnel.

As evidence that this work was effective it is pointed out that no leaks have occurred on protected pipe in this district.

This experience provided facts and figures for management as to what could be done with anodes. Too, it demonstrated what was required for the installation of anodes and that operating personnel could learn the essentials of handling them without a background of specialized technical knowledge. Because there was enough work in each district to justify a man spending full time installing and testing anodes, plans were made to train them.

Early in June, 1949, eight trainees from the various districts were assembled in Tulsa for a five-week training course. Backgrounds of the men varied from skilled laborer to instrument man and none had more than a year of college work. Selection was by district supervisors.

The course of training embraced four weeks of cathodic protection work and one week of observation on an "over the ditch" coating job. The cathodic protection work was divided into two phases, classwork in the mornings and field work in the afternoons. As far as practical both phases were kept in step, but to outline the subjects covered it is best to discuss the classwork and field work separately.

Content of Class Work

Classes started with definitions of electrical units and analogies to gas as this fluid was best understood by the majority of the class. Voltage was compared with pressure drop and amperes (electrons per second) with cubic feet per hour. Milliamperes, milli-

JAMES R. COWLES, since 1939, except for five years in the army, has been employed in the engineering department of Oklahoma Natural Gas Company, Tulsa, Oklahoma. Before the war he made corrosion mitigation studies and since has been in installation work. He holds a BS in engineering from Oklahoma University (1936) and SM degree without subject specification from Massachusetts Institute of Technology. He worked on refinery pilot plants before joining Oklahoma Natural Gas Company.

Abstract

It is proposed that a class of corrosion workers classed as "Technicians" can enable corrosion engineers to cover more lines at less expense than is otherwise possible, particularly if the engineer must operate from a central point while the technicians can be located over the area involved. The training program used, methods taught, and the equipment furnished these personnel by the Oklahoma Natural Gas Company are discussed. A summary of the work done by the men that were trained in June and July, 1949, is given.

volts, and microamperes were explained as variations similar to M.c.f. (thousands of cubic feet) and MMCF (millions of cubic feet). Ohm's law was explained as being simpler than gas flow formulae as no square roots or other powers occur so that a given wire has a constant resistance to flow which is designated in ohms.

Dry cells, 10 and 20-ohm precision radio resistors and 0-1 ampere meters were issued as laboratory equipment and several hours spent calculating current flow in various series and parallel circuits and then checking them with the meter, battery voltage being assumed constant. Best class exercises for the purpose proved to be lighting circuits even though the subject of wattage had to be considered.

Considerable time was spent explaining the galvanometer, voltmeter and ammeter. The potentiometric method of measurement, high resistance voltmeters, low resistance ammeters and shunts were included.

Once the concept of resistance was covered discussion turned to resistivity and the necessity of specifying dimensions of the mass of conductive medium under discussion. The effect of a changing cross section, such as that which occurs around a resistivity prod bar tip, was simulated by using a pyramid of clay. The pyramid rested on a metal plate which served as one current electrode. A fork stuck in the apex served as the other current elec-

trode. Two dry cells served as a current source. Using forks as exploring electrodes the variation in voltage drops over various vertical distances were easily shown. The fact that cross sections around a pipe should be considered as having the shape of a cut of pie was explained.

During this laboratory period a plastic box with metal ends (which were connected to an ohmeter) was filled with distilled water, tap water and finally a few grains of salt were added to the tap water. The fact that water alone was a poor conductor of electricity was obvious as was the small amount of salts required to make a conducting solution.

The trainees were thus given sufficient information to understand Shepard Cane measurements and the small changes in soluble salts within a soil necessary to profoundly affect soil resistivity as well as the fact that the presence of water alone has little significance.

Soil Conditions Discussed

Some time was spent discussing various Oklahoma soil conditions such as alkali spots, salt water creeks, and the fact that color can only serve to tag a particular soil in a given area. Emphasis was placed primarily on the fact that a clay-like soil usually has low resistivity because the slickness of a wet soil seems to be a fair index of soil resistivity at least in central and eastern Oklahoma.

Enough time was devoted to the flow of current in solutions to explain the hydrogen film of polarization and the presence of alkali around cathodically protected pipe.

Next, galvanic action was brought up. Using a damp lump of clay into which could be inserted bright, blued and rusty steel rods as well as carbon, copper, brass, zinc and cast iron rods, the common galvanic combinations encountered were demonstrated and the voltages which occurred were shown on a meter. Soil combinations and differential aeration were explained but not demonstrated.

Once galvanic voltages had been demonstrated, two polished steel rods were placed in a sodium sulfate solution of about 1000 cm-ohms resistivity. Sodium sulfate was chosen to get away from any preconceived opinions concerning salt and acids. The 1000 cm-ohms resistivity was picked as representative of commonly encountered low resistivity soil. A dry cell was connected to these rods and the direction of current flow emphasized. That corrosion occurred at the anode became apparent soon and within a few hours there was little doubt that the same thing had happened to the rod where current was entering the electrolyte as happens to pipe in the ground. The negative rod remained shiny and was cited as an example of how corrosion could be prevented by favorable current flow.

To demonstrate corrosion quickly and to show that the solution around the cathode becomes alkaline, the experiment was also performed in the same solution to which had been added a few crystals of potassium ferricyanide and several drops of phenolphthalein solution. Iron going into solution produced

a blue precipitate and the alkali formed around the cathode produced a pink color.

Extending the experiment, a rod with no battery connected was shown to rust slowly in such a solution while a magnesium rod could be placed in the solution and connected to the steel rod and preserve it as effectively as had the battery and steel anode

When performing the magnesium anode experiment a considerable amount of white precipitate was formed by the corrosion of the magnesium rod. This was later minimized by wrapping the rod with gauze to hold most of the precipitate around the rod. It also affords a realistic imitation of a packaged anode.

Referring to actual pitting of pipe it was pointed out that the flow of current from electrolyte touching the surface of a pit has been measured and that about 0.25 volt has been found to exist between the surface of the pit and the non-corroding portion of the specimen being tested. Cathodic protection was pictured as forcing enouch current onto the non-pitting surface of the pipe being protected to form a hydrogen film which has a pipe-to-hydrogen film surface voltage of 0.25 volt. Then current flow from pits must cease for lack of a driving voltage. Various other conditions, such as mixed control, were not discussed.

Protection Criterion Taught

The principal criterion of protection taught was 0.85 volts pipe-to-soil potential (voltage) whenever possible, considering this to be a measure of electrical suction created to pull current on the pipe. Current flow in bare lines as a measure of control was also taught with emphasis on the fact that current densities of one milliampere per square foot should also exist and a definite change in pipe-to-soil potential (voltage) should occur. It was pointed out also that where low resistivity soil areas are small it is practical to "plant" anodes until the contribution made by an additional anode becomes unreasonably small. Surface potentials were mentioned but not emphasized.

(Obviously better criteria of protection are needed for bare pipe. Perhaps the surface potential method will be developed until it fills this need.)

The placement and size of anodes brought up the subject of readings to remote earth both for resistance and potential. The main point about placement was, of course, the selection of low resistivity soil, moist the year around if protection is to be more than local. Charts correlating soil resistivity and anode drainage and the effect of anode spacing on output were used. The drainage actually found during field work did not correlate very precisely, but it is notable that accuracy is sufficient to predict the correct size of anode. The chart on spacing and number of anodes per group was even less accurate, but afforded a means of working illustrative problems rather than leaving the subject hanging on vague generalities as was necessary in the case of the effect of pipe-to-soil resistance.

When to install anodes was another topic considered. Company policy the last few years has been to

coat all permanent lines. Two common situations had to be examined. On new coated lines the cost of anodes and insulation has proved to be negligible, so anodes were recommended whenever suitable soil to secure drainage by anodes exists. Bare lines and old coated uninsulated lines were placed on leakage record basis. It was felt that rather than to attempt corrosion surveys the more practical and simpler basis is to survey for low resistivity soil suitable for the installation of anodes and thus determine what installations can be made and at what cost. Management's choice is then to compare cost of past or probable leakage with protection cost. This procedure, which follows the theory that anode sites are concurrent with corrosive soil, has beeen found practical.

Insulation Is Emphasized

Another philosophy offered the trainees was to be liberal with insulation and wire connections during the construction of lines. When insulating joints can be substituted for other types of joints that have to exist in any event, or when a flange can be insulated as it is put into place costs are small. If lead wires are attached on both sides of the joint at this time the insulation always can be bonded quickly. Excavating and placing an insulating joint in an operating line is a very different matter. Much the same is true of lead wires. A dozen wires can be installed ahead of the coating patching crew while the line is above ground for the cost of installing one later. Emphasis also was placed on bonding ordinary Dresser couplings as installed. Magnesium anodes do not drain large currents and even welding rod can be used for bonding without fear of excessive voltage drop.

As final instruction on anode performance "Anode Patterns" were presented. These consisted of very simple sketches of representative anode installations which illustrate certain behaviors. Bare, bare insulated, coated uninsulated and coated insulated installations were detailed as to labor, costs, number of anodes required and the technical problems encountered.

Coating Tests Covered

Coating tests where attenuation is negligible were included in the course. Following the suggestion of Messrs. Scherer and Mudd[1] pipe to soil voltages are raised from 0.8 to 0.9 volt and the difference in current noted. Ohm's law then is applied to obtain line-to-soil resistance which can be converted to an average resistance per square foot of pipe surface.

Rectifiers

The subject of rectifiers was introduced by first explaining alternating current. This was explained via the route of a car radio vibrator acting as a double pole, double throw switch. Rectifiers were described as check valves and one or two arrangements to unscramble the reversing flows were shown. It was also felt necessary to describe the possible effects a rectifier has on other structures. No data were given on methods of designing an installation or bonding to foreign lines because these subjects were felt to be too advanced.

Field Work

Field work started with the burying of a packaged anode on a street crossing which was well coated and well insulated and to which a lead wire had been attached in advance. This took about 45 minutes and was calculated to assure the trainees that they were not getting into an extremely complicated job. The remainder of the afternoon was spent learning to use the Cadweld welder, to splice wires and solder.

Next came insulation. Various fittings were shown and an afternoon was spent insulating 6-inch flanges on well heads.

Line current measurements were made with an 0-1 Mv. meter. The flow of current was followed along a line until it was dissipated or went into lines connected to the main trunk line.

Observations of soil resistivity were undertaken along a road cut where various soils were clearly visible. Shepard Canes were used and the small effects of separation and depth of penetration demonstrated. Following practice with the canes the assembly and adjustment of a radio frequency pipe locator was demonstrated and its ability to locate low resistivity soil was shown on a spot of salt laden ground where outlines of the salt pollution were evident on one side but not the other.

Using a new site, teams were sent out along various lines emanating from a compressor station. One team carried soil resistivity test equipment. A second ran line currents. A third team checked insulating joints around the plant by means of an audio frequency pipe locator and an ammeter. The last team checked pipe-to-soil potentials alone one of the lines. Each day different personnel were assigned to each team. When all personnel had been rotated through the various teams one of the lines was protected with magnesium anodes. It was well-coated, well-insulated and only one mile in length, thus all anodes could be placed in an afternoon.

A coated line, not insulated, was chosen for the next anode installation. The much larger current drain required and the loss of pipe-to-soil potential toward uninsulated points was very obvious. The class also attempted to see how much current could be drained from the line by adding anode after anode. After a while it became quite clear that no matter how many anodes were placed at this one spot no increase in drainage would occur.

Using this same group of anodes a nearby bare line was drained and both currents and pipe-to-soil potentials observed.

At this location a pool of salt water was found and different sizes of bare anodes placed in it side by side. Each was connected in turn to a nearby line and drainage observed. The negligible effect of size was demonstrated.

Many times during the field trips, dry cells or a small storage battery were used to illustrate the temporary drainage of structures for test purposes. Metal culverts, steel fence posts, guy wire anchors, other lines and prod bars were used. All but the prod bars represented point drainage whereas these were made to simulate distributed anodes.

Other field trips included the checking of a distributed anode system and a trip to a rectifier. Here instructions were given on checking and adjusting the rectifier and the record system explained.

Locating Pipes Practiced

During this training it will be noticed that pipe locators were used extensively and actual location of pipes practiced. The use of pipe locators as locators of pipe saves time in cathodic protection work, of course, but there is another important point about such devices. Pipe locating equipment issued to districts often falls into disuse after suffering a few minor part failures which the local radio shop seems unable to repair. For this reason trainees were given pocket meters for checking batteries and specifically charged with the maintenance of such locators in their district. It was not contemplated that many of them would make repairs, but knowledge about where to get them repaired, if more than tubes or batteries are necessary, is a valuable aid to keeping them in service.

Text used throughout these classes consisted of Mr. Mudd's[2] manual, a paper which Mr. Simpson of United Gas Company has presented on protection in distribution, plants, as well as a manual prepared to follow the classwork and demonstrations.

Results Are Evaluated

Having reviewed the training furnished it is, of course, interesting to look over the results. Eight men went through the school. Of the eight men trained, seven remain active in full-time corrosion work. Only one man failed to attain skill in the work and this became apparent during the school though he was given an opportunity to learn in his own district if possible.

These technicians have been supplied with equipment and most of them have cars. A few have helpers. They average eighteen anodes per month by the records submitted. Most of these are installed in distribution plants. They have successfully handled old distribution lines, a 50-mile transmission line, and many extensions. Some are even delegating the burying of the anodes to the pipe gang foremen, doing only the surveys and testing. The Shawnee man teamed up with his supervisor and temporarily protected a service line with a thermopile such as that used on automatic furnace controls. Largely, the success of each man hinges on the ability similar to that which would make him successful as a foreman. He must be able to understand the work, of course, but with reasonable aptitude this is apparently quite possible.

The training has been explained as given. Certain modifications are indicated by experience. Ohm's law proved to be one of the most difficult ideas to grasp. Similarly, meter multipliers and shunts also proved very difficult. In looking back then, it appears necessary to be sure that training be with the meters to be used, and these meters should be standardized.

All correction factors like that of lead resistance corrections when measuring line currents with a millivolt meter should be incorporated in the charts which must necessarily be used anyway. To do this lead wires must be specified as to size and length. Equipment should be very complete so that a minimum of improvisation will be necessary.

Instruments should be very rugged and as inexpensive as possible. Three-inch panel meters have been used successfully for all purposes except line currents. A more delicate meter is used for these. Knife edge pointers are not desirable on meters which can be "slammed against the peg." They bend far too easily. All meters should be marked so that it is virtually impossible to select the wrong terminals. An arrow painted on the glass face of the meter with finger nail polish showing the direction of current flow between terminals is helpful during training. Such a mark can be removed quite easily when desired. With some students it may be desirable to mark 0.85 volt on the various scales of the P-S Voltmeter by the same method, especially when the scale divisons are a little difficult to read.

Anode sizes should be limited, perhaps to two.

Tests which are to be performed regularly must be demonstrated and practiced numerous times. This was evidenced by the coating test which was a last minute inclusion and no clear cut demonstration was given. Later a detailed memorandum was sent out. Notwithstanding these efforts, it has been necessary to go out in the field with almost every man before he was able to master the test.

For intensive training it is advantageous to favor selecting men with some clerical experience. These can grasp classwork a little faster than men used to mechanical work only.

Summary

To summarize the experience gained by Oklahoma Natural Gas Company, it can be said safely that the foreman calibre man, young enough to learn a new type of work, can be trained intensively for a few weeks to become a cathodic protection technician capable of working independently. A group of such men can greatly increase the amount of work that will be done in a large company where many routine jobs are encountered. On jobs beyond their capabilities they can relieve engineers of much time consuming testing and checking. The cost of equipping such personnel can be kept within a few hundred dollars, except for transportation. Once available they will be found of real assistance in other ways, such as in locating pipes. Some men will be found that have skills enabling them to do minor electrical work that would otherwise be troublesome to have done.

References

1. L. F. Scherer and O. C. Mudd, *Petro. Eng. Ref. Ann. 1949.* O 27-34 (1949).
2. O. C. Mudd, *Corrosion*, **1, 2**, 192-218, 20-58 (1945) (1946).

The Influence of Stress on Corrosion*

By JULIUS J. HARWOOD

Nature of Stresses

IN CONSIDERING the influence of stress upon the mechanisms and kinetics of corrosion of metals and alloys, it seems desirable to begin with a brief discussion of the nature of stress and a description of the effects of stress upon the internal tructure and characteristics of the metal systems.

What is meant by stress? Stress may be defined as the intensity of force reactions that are set up within a body on the application of external loads, or by non-uniform dilation of the body. Thus all stresses are internal in that they are force reactions existing within the body. Strain is the change in dimensions that accompanies the development of stresses. Strains may be elastic, as when they completely disappear with the removal of the stress, or they may be plastic (inelastic), as when they still exist after the stress has been relieved, leaving a permanent deformation. All stresses in metals produce an elastic strain, which is proportional to the stress. If of sufficient magnitude the stress will also produce a plastic strain.

When a metal is subjected to an external load, as by cold-working, it is deformed, and the deformation or flow behavior can be characterized by the familiar stress-strain diagram shown in Figure 1. Along the linear portion of the curve, the strain is proportional
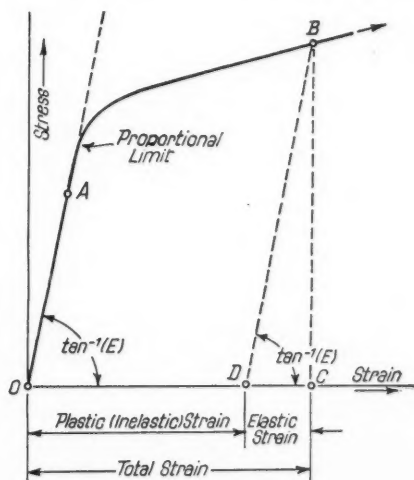
Figure 1—Elastic and inelastic strain. A metal strained to A returns to the original O when the stress is relieved. If stressed to B, the total strain is OC, of which DC is elastic and OD is plastic or inelastic. Upon relief of stress, the relationship between stress and strain is expressed by the line BD. (Gensamer—"Strength of Metals," ASM 1941.)

ABOUT THE AUTHOR—Acting Head of the Metallurgy Section, Office of Naval Research, Navy Department, Washington, D. C., Mr. Harwood has been with the navy since 1941 and with the Office of Naval Research since 1946. He was secretary of the Panel on Corrosion and Surface Protection of the Research and Development Board, Department of Defense and chairman of the former corrosion sub-committee of the joint military Deterioriation Prevention Committee. He is a member of the Inter-Society Corrosion Committee.

Abstract

The effects of stress on the internal structure and energy characteristics of metals are discussed with relationship to their influence on corrosion reactions. The nature and importance of residual stresses and the non-homogeneity of worked metals are emphasized. Recent concepts of the nature of grain boundaries are reviewed and their importance in reactions where stress and corrosion act in a conjoint manner is described. A review of the literature reveals that stresses (either by applied loads or of a residual nature) may influence the nature, rate and distribution of corrosion reactions in several ways: a) by increasing the internal energy level of the metal system and causing a possible shift of electrochemical potential in a more active direction, b) by causing an intrinsic increase in the rate of corrosion, c) by damaging protective surface films, d) by influencing polarization reactions, e) by changing the metallurgical characteristics of the metal system in promoting phase transformations, precipitation, etc., f) by accelerating the rate of corrosion by purely mechanical effects. The exact influence of stress on rates of general corrosion is still questionable, but does not appear to be of major consequence. The most serious effects of stress are in localized corrosion phenomena such as stress-corrosion and corrosion fatigue. Stress-corrosion of alloys is particularly discussed and the influence of metal composition and structure, environment, state and degree of stress is presented. Practically all known alloy systems can be made to crack from stress-corrosion in appropriate environments. The oxide film, mechanical and electrochemical theories of stress-corrosion cracking are reviewed and it is shown that the experimental evidence favors an electrochemical mechanism. However, the exact mechanism of cracking may vary from one metal system to another and no theory presented thus far is adequate to account for all observed phenomena. Stress-corrosion cracking of alpha brass, stainless steels and magnesium alloys is still not understood clearly. Methods of protection against stress-corrosion cracking are reviewed briefly.

to the stress and is elastic. However, above, the elastic limit (Pt. A), this proportionality no longer exists, and plastic deformation has taken place. In complex mechanical processes, such as drawing, rolling and extrusion, the amount of elastic and plastic deforma-

tion that occurs before fracture depends upon the magnitude of the applied loads and the state of stress which is produced (simple axial or multiaxial stresses). The elastic limit is not a well defined physical constant, and often it is most difficult to determine the exact stress value for plastic deformation, even in a simple tension test. Actually, the measured elastic limit seems to be a function of the sensitivity of the extensometers employed, and it has been demonstrated recently[1] by making use of very sensitive strain gauges, that the elastic limit for some metals may be two to three times less in value than the commonly accepted values. It seems conceivable that plastic deformation may occur on a microscopic scale at localized sites under stresses of very small magnitude. The significance of these elastic limit considerations to corrosion reactions will be developed somewhat later in this presentation.

Effect of Stresses On Internal Structure

Of far greater importance to the subject than the formal relationships of stress and strain are the internal changes that occur in metals as a result of plastic deformation. First, it is obvious that work is being done on the metal system, much of which is dissipated in the form of heat. However, a significant fraction of this work, ranging from 5 to 15 percent, is stored up by the metal as latent energy which serves to increase the internal energy level of the system. It is this increase in internal energy resulting from the strain-hardening process to which is attributed the characteristic changes in the physical and chemical behavior of "stressed" metals as compared to unstressed metals. The area under the stress-strain curve for any value of stress and strain, represents the total amount of energy introduced into the metal during the deformation process and has been shown to be as high as 15 calories/gram.[2] As a matter of interest, it has been postulated recently[3] that the latent energy stored by the metal, for a given value of strain, can be
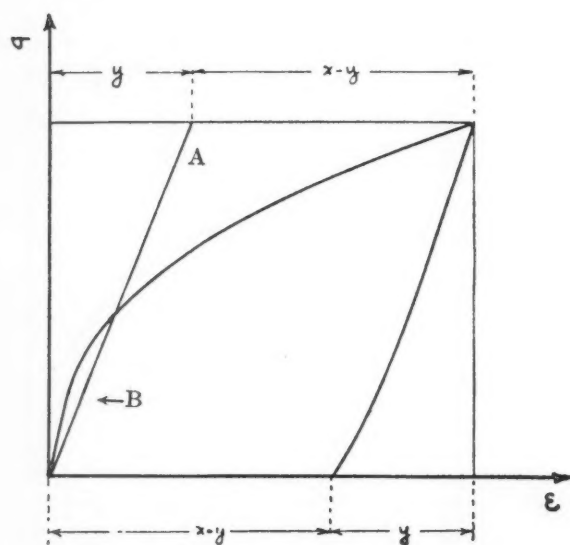
determined from the stress-strain diagram by simple triangulation, as shown by the triangular area marked A in Figure 2. Plastic deformation is generally accompanied by an increase in strength properties, (hardness, yield strength, tensile strength), and a decrease in the ductility properties (elongation to fracture, reduction of area at fracture, impact strength). Taylor and Quinney[2] determined that the absorption of latent energy and increase in strength with increasing strain both cease when the same amount of cold work has been applied and suggested that the strength of pure metals may depend solely upon the amount of cold work which is latent in them. Characteristic changes in physical properties, such as resistivity and magnetic properties, also occur with deformation.

In addition to these property changes, it is of importance to recognize the atomic, crystallographic and microstructural alterations that may occur as a result of deformation. While no more than passing mention can be made of these alterations because of the complex nature of these phenomena. the significance of these sub-microscopic and microscopic changes to the full understanding of the localized corrosion phenomena cannot be over-emphasized. The process of plastic deformation involves such internal disturbances as slip, twinning, warping of crystal planes, rotation and elongation of grains, orientation effects, fragmentation of grains, and a general breakdown of the crystal structure into a highly disorganized state. Cold work breaks up the structure of annealed metal into a disorganized mosaic of crystalline fragments which are not in alignment and which are somewhat similar to the faults and bendings that are found in the earth's crust. The extent to which any of these processes occurs is, of course, dependent upon the magnitude of the strain, the strain rate, and the temperature at which the deformation occurs. In addition, stress (or strain) may cause an increase in the number of nucleation centers and in the rates of nucleation, thereby accelerating solid state precipitation reactions; and may also serve to "trigger" phase transformations such as the transformation of austenite to martensite and ferrite in stainless steels. The most important point to bear in mind is that plastic deformation is essentially a non-homogeneous process, not only from a microscopic point of view but on a macroscopic scale as well.

Slip occurs by the gliding of one layer of atoms over a neighboring layer, but actually it is only about every thousandth layer that so moves. Thus, deformation bands which are visible in cold worked metals represent regions of the deformed grain which have differing orientations as a result of slip on different crystallographic planes.[4] Under a given load, grains of different orientation will take up different degrees of stress even in the elastic range. When slip begins, this stress difference increases, and some grains with favorable orientation yield under a small load while others need higher stresses to achieve the critical shear value necessary for slip. The variation in stress from grain to grain may be as high as 30 percent. This non-homogeneity and anisotropy of the plastic deformation process has been previously measured

Figure 2—Stress-strain curve in which difference in areas A and B represents amount of latent energy stored up by metal after deformation. (Bohenblust and Duwez.[3])
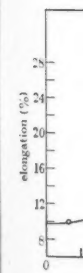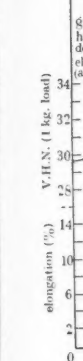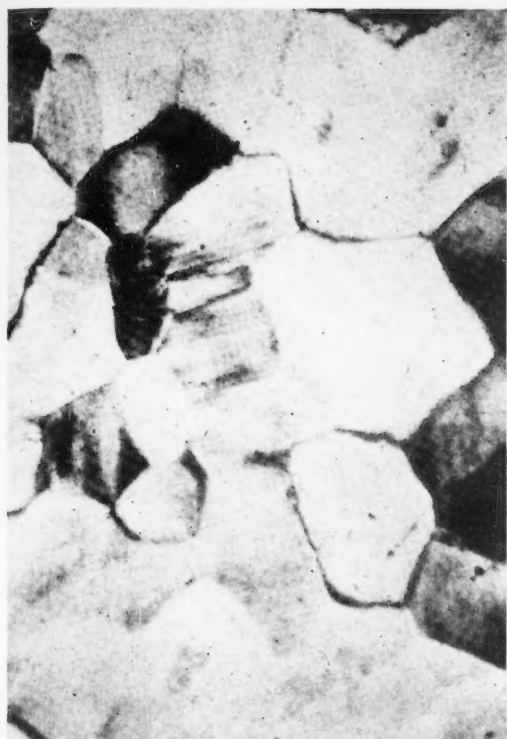
Figure 3—Sheet of silver chloride under plastic extension. The different degrees of darkness correspond to different states of stress. (Orowan.[7])
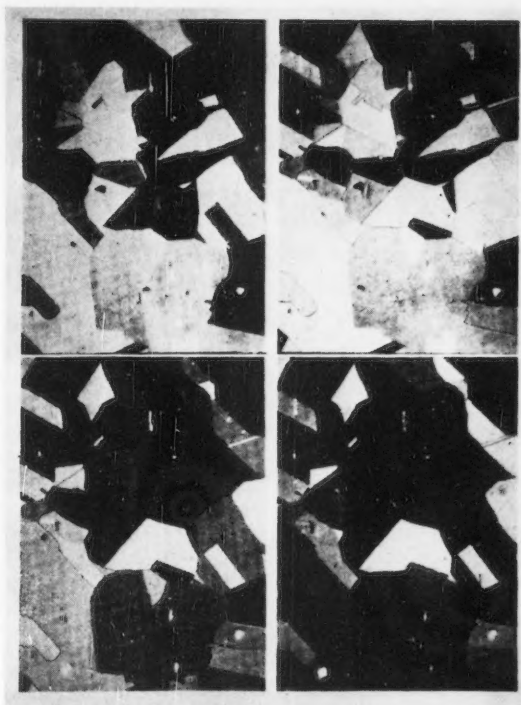
Figure 5—Variations in intensity patterns of a specimen of annealed Monel metal A, with uniform intensity within each grain. X 250 approx. (Woodard.[6])

Figure 6—Variation of intensity within grains indicative of inhomogeneous deformation. Left: X 500, right: X 250. (Woodard.[6])

Figure 4—Top—Hardness and local elongation of the grains after 5 percent elongation. Bottom—Local elongation after 17 percent elongation. (Boas and Hargreaves.[5])

by X-ray techniques, but some recent elegant experiments have demonstrated this effect visually. It has been readily observed in crystals of silver chloride by making use of the photoelastic (change of optical properties as a function of stress) properties of the material. Figure 3 illustrates a sheet of silver chloride under plastic extension. The different degrees of darkness correspond to different states of stress. The same phenomenon has also been demonstrated for aluminum and Monel metal.

By measuring hardness and elongation at numerous points in large grained aluminum specimens, Boas and Hargreaves[5] showed that the deformation varies from grain to grain and within each grain. The deformation near the grain boundary was greater or smaller than at the center according to the extent of deforma-

tion in the neighboring grain. While the hardness was essentially constant within the grains prior to deformation, Figure 4 reveals the variations which were present after straining. Thus, it is apparent that the overall extent of deformation and the average hardness of metals do not indicate the behavior of individual grains.

Using a suitable etchant and polarized light, Woodard[6] showed that plastic deformation produces non-homogeneous conditions of strain within a grain. Figure 5 shows a sample of annealed Monel metal under polarized light, exhibiting uniform color intensity, the difference from grain to grain resulting from differences in crystalline orientation and thus differences in the degree of polarization. Figure 6 shows the same piece after straining. The gradations of intensity within the grains clearly demonstrate the non-uniformity and irregularity of the resultant flow pattern. This non-homogeneous deformation and localized distortion, which may be confined to a small group of atoms or extend over a large group of grains, results in the production of residual ("locked-up") stresses within the metal. Because of the paramount importance of residual stresses to the acceleration of corrosion reactions, it may be worthwhile to briefly discuss the various methods by which residual stresses can be produced.

Residual Stresses

Residual stresses are those stresses existing in materials upon which no external forces are acting. They may be divided into two classes[7] macroscopic residual stresses or body stresses; and microscopic stresses or textural stresses.

Body stresses arise from: a) inhomogeneous plastic deformation produced as a result of cold drawing (in which the surface is in tension and the core in compression) or cold rolling or peening (in which the surface is in compression and the core in tension); b) inhomogeneous plastic deformation due to non-uniform heating or cooling, such as quenching stresses; and c) chemical or structural non-uniformities which result from volume changes due to transformations such as in nitriding and carburizing.

Textural stresses are due to the inhomogeneities which may be present in the material originally (e.g. grain boundaries) or which may occur during the course of straining, heating or chemical changes. Thus, as indicated previously, slip in crystals and varying orientations of grains in plastically deformed polycrystalline materials will contribute to the generation of microstresses. Marked stress gradients can exist across grain boundaries and highly localized severe stresses can also be formed during the process of age hardening or precipitation. Recent theory has it that these stresses exist on a submicroscopic and microscopic scale. A precipitating phase may produce elastic stresses in the surrounding matrix, either because its volume in the unstressed state would be greater than that of the space it occupies in the matrix or because of atomic registry with the matrix. Once overaging or precipitation occurs the atomic fit and elastic stresses are destroyed, and the residual stress intensity falls. Cold working increases the sub-

microscopic and microscopic stresses generated during aging and increases the rate of precipitation.

Of course, these residual stresses can be quite high and may be of such magnitude that it may only require a small addition of strain by external loading to result in cracking. The effects of these residual stresses are not different from the effects of external stresses. It also should be pointed out that heat-treatments which may relieve the macro residual stresses may not be adequate to remove the intense localized micro stresses.

Grain Boundaries and Orientation Effects

The term grain boundary has been mentioned and will recur frequently. The process of intergranular corrosion is a familiar one. It may be of interest to describe briefly contemporary concepts of what constitutes a grain boundary and its properties so as to shed some light upon the role of grain boundaries in corrosion and the influence of stress upon intergranular corrosion. Grain boundaries are, in themselves, regions of stress resulting from the mismatching of adjacent grains with differing orientations. The grain region is, therefore, a transition area of atomic disorder, representing a region in which the atoms of one grain try to align themselves in the same orientation as the atoms of a neighboring grain. In producing this "coherency" elastic stresses are generated. If the degree of orientation dissimilarity is large, then stresses may be quite high. Some idea of the grain boundary disorder may be gained from Figure 7 which is a soap bubble model of the internal solid structure of metals. This degree of disorder in the grain boundary region is representative of a higher energy level and can be responsible for intergranular corrosion. Thus, Chaudron and his co-workers[8] have shown that the rate of etching of the
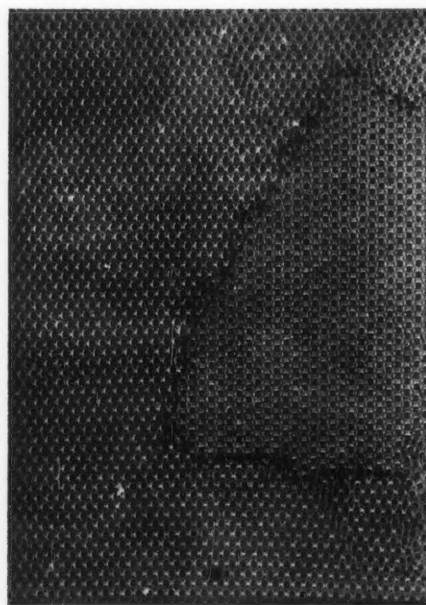
Figure 7—Soap bubble method of metal illustrating grain boundary disorder. Bragg—Institute of Metals monograph "Symposium on Internal Stress in Metals and Alloys," 1948.)

grain bo
more by
than by
aries ir
corrode
grains c
tive ori
straight
occurre
disorde
these in
have a
crystal.
high pu
purity
melting
only di
bounda
tion (g
microso
in samp
be in t
techniq
whereb
grain b
results
upon m
corrosi
genera

Thes
import
an agg
effectiv
neighb
ies also
The ex
differe
demon
extrem
bounda
elemen
stresse
reactio
be anti
to grai

In c
stresse
charac
points
salient
influer

1. S
   t
   s

2. I
   c
   s

3. N
   r

grain boundaries by hydrochloric acid was influenced more by the relative orientations of adjoining crystals than by impurities in the metal itself. Grain boundaries in 99.99 percent Al and 99.998 percent Al corroded at the same rate in specimens containing grains of random orientation, whereas when the relative orientations were nearly identical (or where straight twin boundaries were present) no corrosion occurred. Consistent with the higher energy of the disordered transition structure at the boundaries, these investigators showed that the grain boundaries have a lower melting point than the bulk of the crystal. This also has been shown to be the case for high purity tin.[9] Interestingly enough, when high purity aluminum was heated for 15 hours near the melting point, an inversion of corrosion occurred. HCl only dissolved the bulk of the crystals leaving the boundaries uncorroded as a very thin surviving partition (granular corrosion). By the use of electron microscopy techniques, the width of a grain boundary in samples of ingot iron recently has been shown to be in the neighborhood of 0.5 to 1 microns.[10] X-ray techniques now have been developed to the point whereby regions of the same order of magnitude as grain boundaries can be intensively studied, and the results of these researches will no doubt bear heavily upon many present concepts concerning intergranular corrosion and the nature of grain boundaries in general.

These differences in grain boundary conditions are important in determing the nature of deformation of an aggregate of crystals under stress and can be effective in preventing slip from continuing into a neighboring grain. Regions similar to grain boundaries also have been postulated to exist within grains. The existence of "mosaic" subgrains resulting from differences of orientation within the grains has been demonstrated by experiments on single crystals of extremely high purity aluminum.[11] These subgrain boundaries tend to become regions where dissolved elements concentrate preferentially and where peak stresses also may exist. Their influence in corrosion reactions has not been studied too widely, but it may be anticipated that their role will be somewhat similar to grain boundaries.

In closing this brief and sketchy discussion of stresses and their effects upon the internal structural characteristics of metals and alloys, there are several points that should be re-emphasized, since these are salient to the consideration of how and why stress influences corrosion reactions:

1. Stresses producing plastic deformation increase the internal energy (latent energy) of the metal system.

2. Plastic deformation is a non-homogeneous process. Stress-strain curves measured values of stress, strain, energy levels, etc., are usually "averaging" values and are not representative of localized microstructural conditions.

3. Normal fabricating and processing treatments of metals producing plastic deformation generate residual or "locked up" stresses. These residual stresses may be a more potent factor for consideration in corrosion reactions than service or operating stresses.

4. Orientation differences within grains and between grains, which are accentuated by deformation, are also responsible for the occurrence of residual stresses. The importance of these orientation effects in influencing corrosion cannot be over-emphasized.

5. Stress and deformation can promote or accelerate precipitation reactions and phase transformations.

6. The effects of residual stresses are similar to those produced by external loads.

Influence of Stress on Electrode Potentials

In his excellent presentation last year before the National Association of Corrosion Engineers on the subject of "Why Metals Corrode,"[12] Dr. H. H. Uhlig discussed the importance of dissimilar metal cells in promoting and accelerating corrosion attack. It seems only natural, therefore, in considering the mechanisms by which stress may influence corrosion reactions, to explore first the effects of stress on the electrode potentials of metals. If, as indicated earlier, plastic deformation of metals tends to increase their internal energy, then this energy increase should manifest itself by increasing the heat of solution and by shifting the electrode potential in a more anodic (electronegative) direction.* This is to be expected from the well known relationship.

$$\Delta F = -nfE$$

in which ΔF is the change in the free energy of the system, f is Faraday's constant, n is the number of electrons involved, and E is the electrode potential.

The changes in internal energy accompanying the cold working of metals have been determined by measuring the work done during deformation and the amount of heat evolved, the difference between the two quantities being the plastic strain energy stored in the specimen.[2] The order of magnitude of this energy increase is generally about 1 cal/gm, although under severe work hardening conditions it has been reported to be as high as 15 calories/gm. Conversion of these figures into electrochemical units indicates a difference of potential in the order of millivolts, which generally would be too small to have much influence upon corrosion reactions. Similar values can be obtained by calculations from stress-strain curves using thermodynamic relationships and the area under the curve as a measure of the work involved. However, measurements of these varieties suffer from the same disadvantage in that they provide a "total" or "averaging" figure for the entire specimen volume and are not representative of the actual conditions which may be present at localized sites. Thus, by precision X-ray methods Wood[13] found that, although he obtained an average value of latent energy of 1.7 cal/gm, the

---

latent energy was localized in certain regions of the metal and was not evenly distributed.

It seems conceivable that high stresses existing in grain boundary regions, which may be only several atom layers in thickness, may well serve to induce a localized shift of potential which would be extremely difficult to measure experimentally. In a like manner, the stress concentration of the bottom of a pit or crack would also result in high stress values operating over small volumes of metal. Figure 8 shows the stress distribution at the root of a notch in a bar in tension. As the sharpness of the apex of a crack or notch increases, the stress concentration increases and, at the tip of an infinitely sharp crack, may theoretically approach infinity (Figure 9). Actually, the stress developed never exceeds the flow stress of the material, because deformation would produce "denotching" effects. Under conditions of severe restraint, the fracture stress would be the limiting stress.

Much research[14] has been aimed at the experimental determination of the effect of deformation on electrode potentials with rather contradictory results. Early investigators showed that, within the elastic limit, stress produced an insignificant change in potential, but when plastic deformation took place, the potential difference was as much as 0.01 volt. While these values are low compared to those usually found in corrosion reactions (0.1 volt or greater), they are nevertheless significant. Allowance for the localization of latent energy sites, as previously set forth, may well be sufficient to explain the production of local anodes and consequent localized corrosion attack. Few of these investigations explored the effects of stress on the reversible potential. In many instances, methods of surface preparation may have been responsible for obscure results. The actual metal potential during corrosion reactions is not simply related to the unpolarized potential. Often polarization effects were not considered, thus leaving the significance of the reported values in some doubt.

Some recent research indicating that stress or cold work has a decided effect on potentials reopens once again the question. Using extremely high purity aluminum, Jacquet and Druet[15] have shown that cold working renders the potential in 3 percent NaCl solution about 40-50 millivolts more electronegative than unworked specimens. (Figure 10.) The surfaces of the specimens were prepared by careful electropolishing techniques and precautions were taken not to allow the specimens to come in contact with air. Although the authors emphasized the preliminary nature of their results, nevertheless with all samples tested, the cold worked specimens had an appreciably more active potential than the recrystallized samples. Evans and Simnad,[16] during their studies on the corrosion fatigue of mild steel in neutral chloride solu-

Figure 8—Variation of state of stress across a notched cylinder in tension from the base of the notch to the center line. (Gensamer—"Strength of Metals," ASM, 1941.)

Figure 9—Distribution of stress ahead of a crack that is being wedged open. A tensile stress perpendicular to the crack has the same effect. (Westergaard—"Prevention of Failure of Metals Under Repeated Stress," J. Wiley & Sons, 1941.)

Figure 10—Potential time curve for annealed and cold work specimens of high purity aluminum. (Jacquet and Druet.[15])

tions, investigated the changes in potential under alternating and static stresses. Their measurements under static conditions indicated that compressive stresses gave more noble values than exhibited by the unstressed specimens, whereas for specimens under tension, the values tended to be more electronegative than those obtained without stress. However, under long-time tests the same value was reached in all cases whether the test area was under compression, tension, or unstressed. The authors interpreted their results to suggest that below the elastic limit, the effect of stress on the potential of metal not covered with a protective corrosion film is negligible, and that if films are present, the stress only affects the potential by altering the state of repair of the film covering the surface. They further suggested that stresses within the plastic range (or residual stresses resulting from plastic deformation) depress the potential of the metal itself, irrespective of any film damage. The authors continued their studies of corrosion fatigue of cold drawn steel in acid solutions[17] in order to distinguish between the effects of film rupture and that of the distortion of the underlying metal in accelerating fatigue cracking, and once again measured electrode potentials as a function of stress. In these tests, a definite effect of stress was observed. Figure 11 shows that, although there is little initial difference between the curves obtained at various ranges of stress, shortly before final fatigue failure the potentials began to decrease and differed from one another appreciably. These potentials were well below the steady potential obtained at zero stresses in long continued experiments. This stands in marked contrast to the experiments in salt solution, where, although the rate of fall of potentia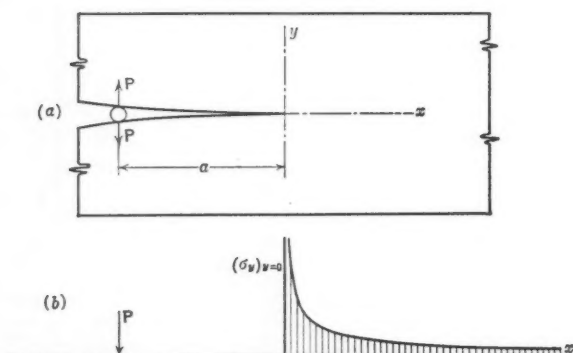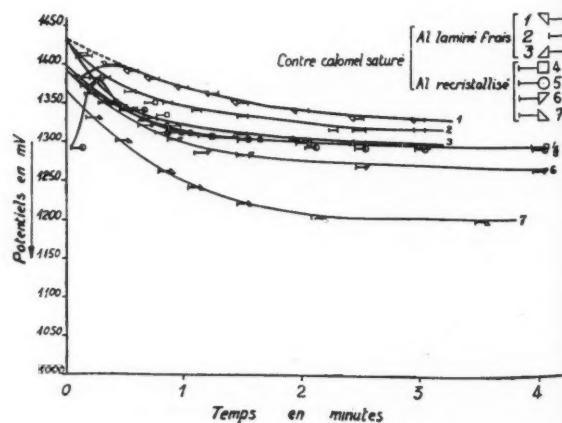l increased with stress range, the same final value was reached in all cases. The interpretation of these results was that the changes in potential were coincident with increased corrosion velocity and that both occurred when corrosion fissures and pits became extended into cracks which produced appreciable distortion of the metal and disruption of the crystalline structure, thus making the metal more reactive. Of significance also (see Figure 11) is the time potential curve for the annealed sample which is always at a more noble potential than the cold drawn specimens. The final steady potential of the annealed specimen differs from that of the cold drawn ones by over 40 mv.

Recent work at the Institute of Study of Metals (University of Chicago)[18] has indicated that electrodes of EMF cells, subjected to compressive or tensile stresses, develop potential differences with respect to unstressed electrodes. The sign of the potential difference depends upon whether the stress is in tension or in compression. In either case, the effect is reversible and proportional to the load in the elastic region.

Not to be overlooked in this respect is the work of numerous German investigators, who, as a result of their stress-corrosion studies of aluminum alloys, seemed convinced that stresses caused electrode potentials to shift in an anodic direction[19] and postulated that the lowering of potential resulting from the stresses existing at the apex of advancing intergranu-

lar cracks were responsible for the difference in speed between intergranular corrosion and stress corrosion. There does not appear to be much experimental evidence offered by these investigators to support the claims of potential shift with stress, although Bosshard[20] showed that after seven days corrosion 93 precent cold worked aluminum was appreciably more anodic than 50 percent cold worked aluminum by as much as 700 mv. The results are shown in Figure 12. It seems evident that polarization effects and other factors may be important in the interpretation of these results. It is noteworthy to add that Mears[21] has reported a negligible effect of stress on the potentials of aluminum alloys and brass.

The chief conclusion that can be drawn from a review of the published results on the effects of stress and cold work on the electrode potentials of metals is that, despite the increasing experimental evidence pointing to a more electronegative potential under the influence of tensile stress, much research remains to be done to clear up the existing confusion and to definitely establish the role of stress. More high purity homogeneous metal systems need to be studied in particular high purity single crystals to avoid the complexities of grain boundaries. Special attention must be paid to methods of surface preparation to avoid surface distortion and film formation, and the polarization behavior of the metal system in specific environments must be considered to clearly differentiate any effects of stress. Consideration also should
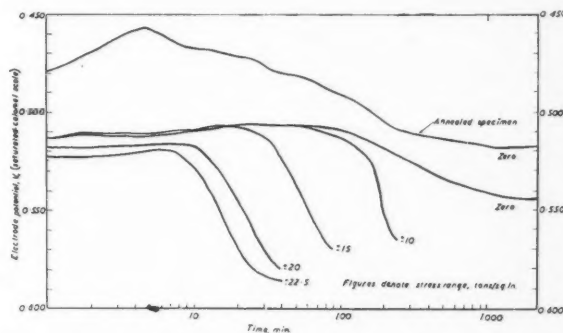

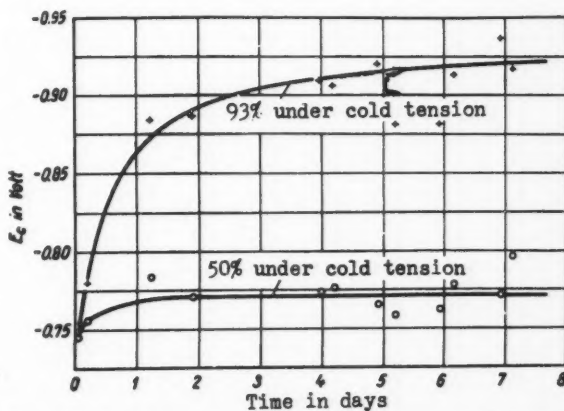Figure 11—Influence of stress range on time potential curves. (Evans and Simnad.[17])

Figure 12—Potential-time curve for cold worked aluminum. (Bosshard.[19])

be given to the possible influence of preferred orientation in cold worked polycrystalline metals because considerable evidence shows that crystal orientation is a significant factor in the electrochemical and corrosion behavior of metals. For example, in acetic acid containing hydrogen peroxide, the [111] faces of a copper single crystal dissolve slightly faster than the [100] faces and about twice as fast as the [110] faces.[22] Similar effects have been observed in phosphoric acid.[23] Walton[24] found that the [111] plane of aluminum single crystals dissolved appreciably faster in HCl than the [001] plane, but observed no difference in potential between these two crystallographic orientations. However, Morize[25] has recently shown that the [111] face of a single crystal of aluminum is about 50 millivolts more electronegative in mild acid than the [001] face; the [111] plane having a potential of —1.20v and the [100] plane a potential of —1.15v. These results were in accord with the dissolution rates of these same faces in acid. Similarly the (0001) face of zinc single crystals was the most anodic and also exhibited the greatest reactivity.

Influence of Stress on Rates of Corrosion

The published evidence pertaining to the influence of stress on rates of general corrosion should be examined next. As in the case of electrode potentials, the situation is also somewhat confused. Some authors have found stress to increase corrosion; others have observed no effects; and there are reported cases of stress decreasing the rate of corrosion. It appears that there is no consistent change in corrosion rate with stress; rather the effects are quite specific, both for the metal and the environment. In many of the published studies, other factors such as composition, impurities, film formation, etc., overshadowed the effects of stress. Evans[26] and others have reviewed the literature extensively. Only a few of the results will be cited. Tammann and Neubert[27] found that cold working greatly accelerates the action of HCl on aluminum and magnesium, although Loose[28] reported no effect of cold work on the general corrosion rate of high purity magnesium. Friend[29] found that straining increases the rate of attack of dilute sulfuric acid on iron, although he found no difference in rates of corrosion in sea water between strained and unstrained iron. This is explained on the following basis: in aerated salt solutions, the corrosion rate is largely controlled by the oxygen supply, and there should be no reason why strained iron should have a readier access to supply of oxygen. Friend's results were confirmed by Skapski and Chyzewski[30] who found that the pH of a solution should be below four before the effect of cold work becomes appreciable. Beerwald and Groeber[31] showed that the hydrogen evolved from an aged aluminum-magnesium alloy by reaction with dilute HCl was more than doubled if the specimens were plastically deformed first. An interesting effect was described by Whitely and Hallimond[32] who reported that, when cold worked steel was dissolved in 33 percent nitric acid, more nitrogen and ammonia and less oxides of nitrogen were liberated than from the same steel in the annealed condition.

They ascribed the effect to the greater energy content of the strained metal. Data published by the International Nickel Co.[33] reveal no consistent nor definitive results concerning the effect of cold work upon the corrosion of nickel, Monel, and Inconel in various solutions.

These references are only a few among the many in the literature. The preponderance of evidence seems to indicate that the influence of strain upon general corrosion rates is small and not of major practical significance, although where acid attack is involved (at least for steels) a small but real increase does result. For corrosion under conditions of oxygen depolarization control, it seems apparent that the presence of stress should have no influence.

This apparent minor effect of stress on general corrosion rates does not seem contradictory to or inconsistent with the previous discussion on the effects of stress on the internal energy and structure of metals and on electrode potentials. The inherent, non-homogeneous effects of plastic deformation would indicate that the major contribution of stress in corrosion would be in its effects on the distribution of the corrosion reaction, i.e. in causing localized corrosion. Abundant evidence exists indicating that such is the case and that stress causes localized attack not only by increasing the electrochemical activity of the metal in local sites, but also by damaging protective surface films, by influencing polarization reactions, and by altering the metallurgical characteristics of the metal system. An intrinsic increase in corrosion rates in localized reactions also may be produced, as well as an acceleration of failure by purely mechanical aspects. These factors will be discussed in some detail in the discussion of stress-corrosion which provides the major text of this presentation, but an introductory discussion of these effects may be salutary.

The difference in potential between worked and unworked areas of an iron specimen, and the resultant galvanic cell, can be neatly demonstrated by hammering one-half of a length of soft iron wire and placing the wire in a glass dish, then covering it with a hot solution of gelatin containing sodium chloride, potassium ferricyanide and phenolphthalein. On cooling, the gelatin sets in and prevents the mixing of the cathodic and anodic portions of the jelly. At the anodic hammered end, ferrous ions go into solution and react to form the characteristic blue precipitate of ferrous ferricyanide. At the unhammered cathodic end, hydrogen ions are discharged and the gelatin becomes alkaline as indicated by the pink coloration arising from the phenolphthalein. Similarly, it has been shown[34] that a stressed specimen of a magnesium base alloy (AM-C57S-H) was anodic to an unstressed specimen in a $NaCl-K_2CrO_4$ solution. The

Figure 13—Current flow-time curve for stressed Mg alloy-unstressed Mg alloy couple in $NaCl-K_2CrO_4$ solution. (Mears, Brown and Dix.[34])
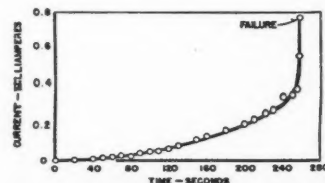
current flow-time curve shown in Figure 13 reveals an auto-catalytic effect, the current increasing tremendously just before failure of the specimen. A somewhat similar effect was observed by Evans and Simnad, who in the above mentioned corrosion fatigue studies, found that the corrosion rate increased markedly shortly before fracture. They attributed the inherent increase in corrosion velocity to the increased metal reactivity at the root of the advancing crack resulting from the distortion of the metal structure. Thus, this increase in rate of corrosion or current flow, presumably due to the large stress concentration at the tip of an advancing crack, represents a true condition of stress-accelerated velocity of corrosion. The existence of strained-unstrained metal galvanic cells was also observed by Coffin and Tingley[35] in their study of the exchange of silver ions between aqueous solutions and surfaces of metallic silver. When they used cold worked samples of silver, which had crystalline areas existing among the strained mass of metal, they noted that the crystalline areas received a deposit of metallic silver, resulting from the electrochemical action of the strained metal anode and the unstrained metal cathode. They also obtained evidence indicating that the worked specimens were more reactive than crystalline specimens, exhibiting a greater ion exchange.

Using radioactive cobalt, Simnad and Ruder at Carnegie Institute of Technology also have demonstrated that ion exchange occurs as a result of local cell action.[36] A large grained annealed cobalt specimen was deeply etched so that the grains were at different depths from the original surface. Polishing on fine grained emery paper then cold worked those grains nearest to the specimen surface. Exchange experiments in solutions of radioactive cobalt ions indicated that all the "exchange" took place on the undisturbed grains. This is believed to be a consequence of the local cell action which results from the difference in potential between the cold-worked and annealed portions on the surface. The annealed parts are cathodic and thus the cobalt ions in solution preferentially deposit on these sites rather than on the anodic cold worked regions.

Strain may influence markedly the distribution of corrosion attack by causing a rupture of surface films. Thus, a strip of metal which has been exposed to air, then bent and immersed, often suffers preferential corrosion at the bend, particularly on the convex side where the film will have suffered most. This has been demonstrated by Evans,[37] who bent a finely abraded copper specimen immediately after grinding and then immersed it at once in silver nitrate. General blackening was observed over the entire specimen. If, however, the abraded sheet was stored in dry air for several days and then bent, the silver nitrate test revealed a greater local deposition of silver along the bend axis where the film was damaged. If the abraded bent specimen was similarly stored in dry air, the silver nitrate test caused no special attack at the bend, indicating a "healing" of damaged film. Simnad[38] cites similar results of stress on passive films. If iron is passivated by dipping in concentrated nitric acid and is then bent before being
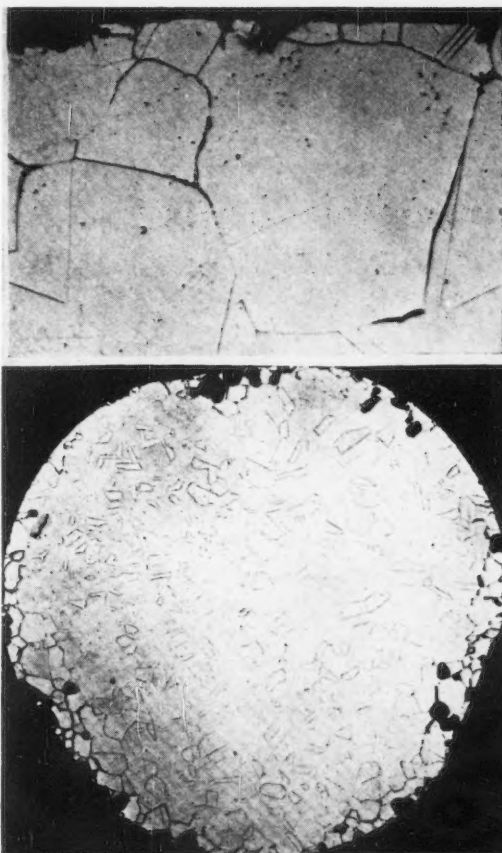
Figure 14—a) Top—alpha brass, fully annealed. Intercrystalline penetration. X 100 approx. b) Bottom—alpha brass, annealed and squeezed in lathe chuck. Deeper intercrystalline penetration than in Figure 14a. X 7.5 approx. (Whitaker.[40])
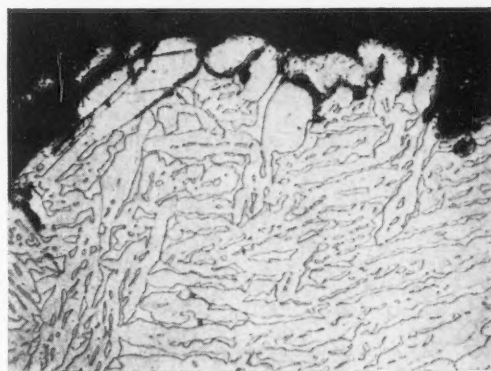
Figure 15—Alpha-beta brass, fully annealed. Slight penetration along phase boundaries. X 200 approx. (Whitaker.[40])

placed in dilute nitric acid, it is violently attacked at the bend where the stresses are greatest and the protective film is broken.

Robertson[39] recently studied the effects of tensile and compressive stresses on the corrosion of a high strength aluminum alloy (24S). He found that when the metallurgical structure of the alloy was such as not to render it susceptible to intergranular corrosion, pitting corrosion occurred in immersion in NaCl-

H_2O_2 solutions, and that tensile stresses accelerated the rate of corrosion while compressive stresses decreased the corrosion rate. The differences in corrosion rates between stresses and unstressed samples were quite small, but significant and real. The effect was attributed to the probable rupture or compression of the oxide film which would respectively promote or inhibit access of the electrolyte to the underlying metal. When the alloy was aged at an elevated temperature, so as to render it susceptible to intergranular corrosion as a result of localized precipitation at the grain boundaries, intercrystalline corrosion occurred irrespective of the type of applied stress. However, in this case, the applied tensile stress accelerated the rate of corrosion, whereas the form and rate of attack were the same for corrosion under an applied compressive stress and in the unstressed state. Thus, in this instance, the function of the tensile stress is that of an accelerator only and not as a primary component of the mechanism of intergranular corrosion. But as will be seen later this
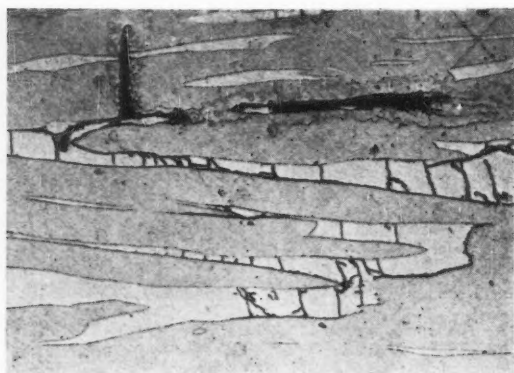
is not always the case. Applied or residual stresses well may induce precipitation reactions or other types of phase transformations which would then render the metal susceptible to intergranular corrosion or other types of localized corrosion. Thus, the strain etching of steels, which has become such a useful tool in criminological investigations, is believed by many to be a result of a precipitation reaction of an intermetallic compound of iron as a result of prior working.

Some particularly interesting effects of cold work on the corrosion of brasses in ammoniacal environments recently have been reported.[40] In moist ammoniacal atmospheres, in the absence of stresses, fully annealed brasses, consisting of all α, α-β, or β structure, suffer intercrystalline penetration. In α-β alloys and pure β alloys, the penetration is slight. In the case of α brass, prior deformation or the application of stress accelerated the intergranular penetration (Figure 14). With the α-β alloys, cold work changed the attack from a penetration along the phase boundaries, Figure 15, to a network of transcrystalline cracks in the β phase, Figure 16. With the pure β alloys, the original slight intercrystalline penetration (Figure 17) was transformed to a deep transcrystalline cracking, Figure 18. Susceptibility to this transgranular cracking of the α-β and β alloys was eliminated by a low temperature anneal after straining.

Thus, it is seen that the influence of stress in corrosion reactions is principally one of localizing the reaction or changing its distribution by any of several mechanisms. In such localized reactions, the velocity of corrosion is increased also by the presence of large stress concentrations at the tip of corrosion cracks and failure can be accelerated by purely mechanical effects acting on reduced cross sections. The two best known corrosion phenomena in which stress is involved are stress-corrosion and corrosion

Figure 16—Alpha-beta brass, annealed and squeezed in lathe chuck. Transcrystalline cracking in beta areas. X 500 approx. (Whitaker.[40])
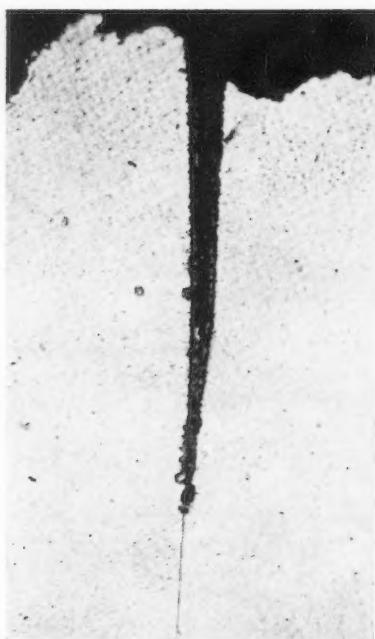
Figure 17—(Left) Beta brass, fully annealed. Slight intercrystalline penetration with dezincification. X 500. (Whitaker.[40])

Figure 18—(Above, right) Beta brass, fully annealed and squeezed in lathe chuck. Deep transcrystalline cracks permeating the whole section. X 7.5. (Whitaker.[40])

1. B. Av
2. G. I.
3. H. F
   Sept;
4. C. Ba
5. W. F
   (1948
6. D. H
7. E. O
   Alloy
8. G. Cl
   854 (
9. B. Cl
10. J. F.
11. P. La
   Sept.
12. H. H
13. W. A
14. U. R
   p. 42
   W. F
   (19
   C. F
   P. D
   T. T
   (19
15. Y. I
   (194
16. U. R
   (194
17. M. T
   531 (

fatigue. The problem of stress corrosion has been touched on several times in the above discussion and it is now proposed to consider it in some detail. It is hoped that this somewhat lengthy introduction has served to provide a broad background for considering the complex phenomena which are to be discussed.

References

1. B. Averbach. Private communication.
2. G. I. Taylor and H. Quinney. *Proc. Roy. Soc.* **143A**, 307 (1934).
3. H. F. Bohnenblust and P. Duwez. *J. App. Mech.*, 222 1948 Sept; *Trans. ASME*, **70**, 222 (1948).
4. C. Barrett. *Trans. AIME*, **135**, 140 (1939).
5. W. Boas and M. E. Hargreaves, *Proc. Roy. Soc.*, **193A**, 89 (1948).
6. D. H. Woodard, *J. Metals*, **1**, 722 (1949) Oct.
7. E. Orowan. Symposium on Internal Stress in Metals and Alloys, Inst. of Metals, London, p. 47 (1948).
8. G. Chaudron, P. LaCombe and N. Yannaquis. *Nature*, **162**, 854 (1948) Nov. 27.
9. B. Chalmers. *Proc. Roy. Soc.*, **175A**, 100 (1940).
10. J. F. Radavich. *J. Metals*, **1**, 395 (1949) July.
11. P. LaCombe and L. Beaujard. *J. Inst. Metals*, **74**, 1, (1947) Sept.
12. H. H. Uhlig. *Corrosion*, **5**, 169 (1949) June.
13. W. A. Wood. *Phil. Mag.*, **18**, 495 (1934).
14. U. R. Evans. Metallic Corrosion, Passivity and Protection, p. 421 (1946).
    W. H. Walker and C. Dill, *Trans. Electrochem. Soc.*, **21**, 153 (1907).
    C. F. Burgess. *Trans. Electrochem. Soc.*, **23**, 17 (1908).
    P. D. Merica. Natl. Bur. Stan. Tech. Paper 83, (1916).
    T. Turner and J. Jevons. *J. Iron & Steel Inst.*, **111**, 169 (1925).
15. Y. Druet and P. A. Jacquet. *Metaux et Corrosion*, **22**, 139 (1947) Sept.
16. U. R. Evans and M. T. Simnad. *Proc. Roy. Soc.*, **188A**, 372 (1947).
17. M. T. Simnad and U. R. Evans, *J. Iron & Steel Inst.*, **157**, 531 (1947) Aug.
18. N. H. Nachtreib, Private communication.
19. C. A. Naugle. German Theories and Accomplishments in the Field of Stress Corrosion Cracking. Air Material Command Tech. Report FT-R 1131-ND (1947) June.
20. C. A. Naugle. ibid., p. 59.
21. R. B. Mears. *Metal Progress*, **48**, 105 (1945).
22. R. Glauner and R. Glocker, *Z. Krist.*, **80**, 377 (1931).
23. A. T. Gwathmy and A. F. Benton. *Trans. Electrochem. Soc.*, **77**, 211 (1940).
24. C. J. Walton. *Trans. Electrochem. Soc.*, **85**, 239 (1944).
25. P. Morize. *Metaux et Corrosion*, **22**, 71 (1947).
26. U. R. Evans. Metallic Corrosion, Passivity and Protection, p. 433 (1946).
    H. R. Copson. Corrosion Handbook, p. 576 (1948).
27. G. Tammann and F. Neubert. *Zeitsch Anorg Chem.*, **207**, 87 (1932).
28. W. S. Loose. Corrosion Handbook, p. 231 (1948).
29. J. N. Friend. *Carnegie Schol. Mem.*, **3**, 374 (1911).
    J. N. Friend. *J. Iron & Steel Inst.*, **117**, 639 (1928).
30. A. Skapski and E. Chyzewski. *Metaux & Corrosion*, **13**, 21 (1938).
31. C. A. Naugle. loc. cit., 68.
32. H. Whitely and A. Hallimond. *Carnegie Schol. Mem.*, **9**, 1 (1918).
    H. Whitely and A. Hallimond. *Carnegie Schol. Mem.*, **14**, 163 (1925).
33. "Corrosion." International Nickel Co. (1944).
34. R. B. Mears, R. H. Brown and E. H. Dix, Jr. Symposium on Stress Corrosion Cracking of Metals, (ASTM-AIME)
35. C. C. Coffin and I. I. Tingley. *J. Chem. Phys.*, **17**, 502 (1949).
36. M. T. Simnad. Private communication.
37. U. R. Evans. Metallic Corrosion, Passivity and Protection, p. 434 (1946).
38. M. T. Simnad. *J. Electrochem. Soc.*, **97**, No. 2, 31C (1950) Feb.
39. W. D. Robertson. *Trans. AIME*, **175**, 428 (1948).
40. M. E. Whitaker. *Metallurgia*, **39**, 21 (1948) Nov.

DISCUSSIONS ARE INVITED

Readers who wish to submit written information additive to articles published in CORROSION, or who wish to register differences of opinion with respect to any articles are urged to send such discussions to Dr. F. N. Alquist, Chairman, NACE Editorial Review Committee, Organic Research Laboratories, 20A Building, Dow Chemical Co., Midland, Mich. Doctor Alquist will submit such discussions to a member of the review committee, and after review and approval the discussion will be published.

The expression of opinions about or the addition of information to that contained in technical articles will advance the interests of NACE and make CORROSION more valuable to the membership.

Some Aspects of the Corrosion Of Tin Plate by Prunes *

By V. W. VAURIO

Introduction

CONTAINERS for various foods account for a large portion of the tin plate manufactured. Tin plate used for food containers should possess a sufficient resistance to corrosion to assure that the resulting containers will have an adequate "shelf life." A further consideration is that tin plate be produced as cheaply as possible.

The necessity for conserving tin during the recent world conflict resulted in the development of electrotinning facilities that permitted the production of tin plate having much lighter tin coating weights than those possible in the conventional hot-dip tinning process. The successful utilization of this new tin plate for containers for the less corrosive foods has been adequately reported[1, 2, 3] and needs no further elaboration. As might be expected, this new development in tin plate manufacture introduced a new series of studies on the various factors which affect the corrosion resistance of tin plate.

The present discussion pertains to certain experimental evidence which offers an explanation of the mechanism of tin plate corrosion by prunes and, possibly, by some other fruits. It is recognized that foodstuffs vary considerably in corrosiveness, and it is logical to expect that the mechanism of corrosion may be vastly different for different foodstuffs. The conclusions drawn from experiments with prunes are, therefore, not necessarily applicable to the corrosion of tin plate by other food products. Each product or class of product should be investigated independently.

The corrosion of lacquered tin plate, either as containers or as glass jar closures, is beyond the scope of this paper. Enough work has been done on this problem to indicate that the corrosion mechanism of lacquered tin plate-food product systems differs so radically from that described in this paper that conclusions drawn from the prune pack tests are not necessarily applicable to corrosion problems involving lacquered tin plate.

Food Pack Test

The research laboratory of the Carnegie-Illinois Steel Corporation is conducting systematic studies of the influence on corrosion resistance of the separate processes involved in tin plate manufacturing. Corrosion tests on tin plate to date have been confined to one food product and low carbon steel.[4] Corrosion resistance is evaluated by means of experimental

★ A paper presented at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

ABOUT THE AUTHOR—For the past six years V. W. Vaurio has been with the Research Laboratory of Carnegie-Illinois Steel Corp. investigating tin plate quality, at present holding the title of Research Associate. His work has been confined largely to tin can and tin plate problems, 8 years with American Can Company and 6 years with Tennessee Coal, Iron and Railroad Co. He holds a BS degree from Hamline University, St. Paul, Minn. and an MS from Northwestern University.

Abstract

The mechanism of corrosion of tin plate in cans has been investigated by the prune pack method. Evidence is presented which indicates that, in prunes at least, tin corrodes at a constant rate without the evolution of measurable quantities of hydrogen. Hydrogen evolution in canned prunes is related directly to the solution of the iron of the steel base. Above a certain minimum tin coating weight, this minimum being dependent upon the character of the steel base, increased tin coating weight, up to at least 1.5 pounds per base box, results in increased pack life. The improvement in pack life per increment increase of tin coating weight is the same for all types of steels investigated. Experiments are described which illustrate that tin affords cathodic protection to steel in contact with prunes. The more corrosion resistant the steel, the more effective is the cathodic protection. These tests indicate that porosity of the tin coating is not an important factor in the corrosion of plain (unlacquered) cans by prunes. These conclusions do not necessarily apply to other food products packed in plain tin cans or to food products packed in lacquered cans.

packs of prunes and water, or prune juice, in specially fabricated cans stored at 100° F. The "pack life" of a can is the time to produce sufficient hydrogen to bulge either end of the can. Standard profile, size No. 2 (307 diameter, i.e. 3-7/16 inches diameter) test ends are fabricated from the test plate and are double seamed to commercial, full enamel-lined (lacquered) cans which have been additionally protected by a spray coat of lacquer on the side seam area of the inner surface (side seam striped). In such a container, practically all of the corrosion is confined to the unlacquered test end, which, in the pack test, is the bottom of the can and is thus in constant contact with the food product. Use of this type of test can eliminates the extensive equipment necessary for fabricating the entire can from the test plate. Prune pack data indicate a satisfactory correlation with test

results obtained with plain (unlacquered) cans entirely fabricated from the test plate. Figure 1 illustrates the prune pack ratings obtained on different tin plate lots in fair comparative tests.

The canning procedure employed for these tests was very carefully controlled. Dried prunes (40-50 count) were blanched in boiling water for 5 minutes and drained. Each can was filled with 9⅔ ounces of blanched prunes. Hot tap water (206° F) was added to fill. The filled cans were exhausted of air in a closed steam box for 5 minutes at 212° F, after which the fill-in volume was adjusted by a displacement plunger or "topper" so as to provide a 3/16 inch head space. The cans were sealed with the test end and processed 30 minutes at 212° F, then cooled in water to 100° F. In the prune juice experiments the cans were filled with hot juice, exhausted, fill-adjusted, processed and cooled as described above.

Dried prunes and bottled prune juice (aqueous extract of dried prunes) are available in quantity the year round, and, despite some expected variation in corrosiveness from lot to lot, use of these products as corrosion media has proved reasonably satisfactory. Although the mechanism of corrosion may be different for prunes as compared to that of other products, it has been assumed that the results obtained by prune packs would probably be applicable to many of the acid food products.

During the course of investigations related herein, certain interesting observations were made which may be stimulating to other investigators studying tin plate corrosion. These will be apparent as the discussion proceeds.

Determination of Rate of Solution of Tin and Iron from Tin Plate by Prunes

From a group of cans stored at 100° F, multiple (3 to 5) samples were withdrawn periodically for analysis of the contents for tin and iron. The usual procedure was to macerate and blend the fruit pulp and liquid from a single can in a mechanical "liquidizer" (Waring Blendor), after the pits, if present, had been removed. The blended pulp and liquid were
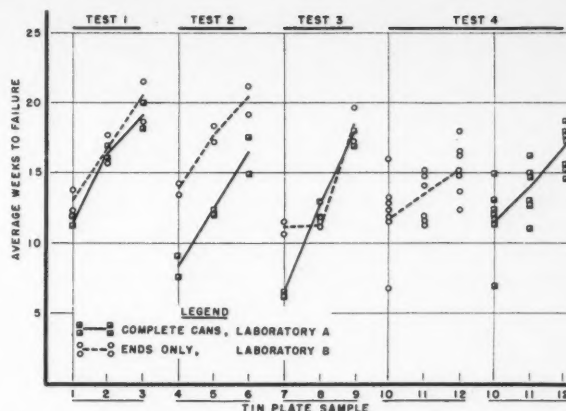

Figure 1—Prune pack corrosion ratings of 0.50-lb. electrolytic tin plates obtained by two laboratories, one testing complete cans and the other testing ends only.

"wet ashed" with sulphuric and nitric acids. Iron was determined colorimetrically by the α,α'-Dipyridyl method. Tin was determined volumetrically by oxidation with iodine.

For a given lot of prunes, the average rate of solution of tin at 100° F is constant with time, irrespective of the thickness of the tin coating, the type of tin deposit (i.e. hot-dipped or electro-deposited from acid or alkaline plating baths), or the corrosion resistant quality of the steel base. (See Table I.) The tin is dissolved by prunes, under the test conditions imposed, at a rate equivalent to the loss of about 0.03 pound per base box* per week. The solution rate in commercial prune juice is about 0.04 pound per base box per week. Measurable solution of tin occurs during the sterilizing process, the amount being dependent on the time and the temperature of sterilization. Figure 2, which shows the results of one experiment, is typical of this relationship. About

* One base box is equivalent to 62,720 square inches of surface (area of 112 sheets 14 x 20 inches). The exposed area of a 307 end is approximately 8.5 square inches which is equivalent to 8.5 ÷ 62,720 = .000136BB. 1.00 pound per base box tin coating is equivalent to 453,590 milligrams per 62,720 square inches, or 61.8 milligrams per can end on one surface.

TABLE I—Analysis of contents of random cans after various periods of time
(Sn and Fe expressed as mg per can, Failures as cumulative per cent)

Wks.	Pack 8 0.50 Pound Electrolytic (Acid Electrolyte)			Pack 13 0.50 Pound Electrolytic (Acid Electrolyte)			Pack 13 0.50 Pound Electrolytic (Alk. Electrolyte)			Pack 41 0.75 Pound Electrolytic (Acid Electrolyte)			Pack 41 1.00 Pound Electrolytic (Acid Electrolyte)			Pack 41 1.25 Pound Hot Dip		
	Sn	Fe	Failure	Sn	Fe	Failure	Sn	Fe	Failure	Sn	Fe	Failure	Sn	Fe	Failure	Sn	Fe	Failure
2	9.0	0	0	11.2	0	0	10.9	0	0	8.9	0	0	6.0	0	0	6.7	0	0
4	14.0	3	0	14.9	0	0	16.3	0	0	15.8	0	0	12.7	.7	0	10.6	0	0
6	21.0	14	0	17.3	0	0	21.1	1.5	0	16.6	1.7	0	15.9	1.5	0	19.2	2	0
8	25.0	21	0	23.9	0	0	19.2	4.0	0	24.4	0.1	0	14.9	1.8	0	23.7	0	0
10	....	31	18	21.6	0	0	22.7	20.9	0	23.4	4.1	0	18.4	1.0	0	26.9	1	0
12	29.0	93	46	29.1	7.7	0	24.2	49.6	0	31.6	4.3	0	23.7	2.0	0	30.7	2	0
14	....	..	100	....	45.8	6	25.5	86.5	32	33.5	3.9	0	32.8	3.2	0	30.3	2	0
16	....	....	....	....	57.0	23	....	120	98	....	....	0	....	....	0	....	....	....
19	....	..	....	....	120	66	....	....	100	42.1	17.4	5	37.4	2.7	0	41.7	2	0
20	....	..	....	....	....	100	....	....	....	....	..	18	....	....	0	....	....	0
22	....	..	....	....	....	....	....	....	....	46.0	96.0	69	49.2	1.7	0	51.7	3.5	0
24	....	..	....	....	....	....	....	....	....	....	..	100	....	....	0	....	....	0
26	....	..	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	0
28	....	..	....	....	....	....	....	....	....	....	....	....	....	....	5	....	....	0
30	....	..	....	....	....	....	....	....	....	....	....	....	59.3	101.0	15	53.0	70.3	15
32	....	..	....	....	....	....	....	....	....	....	....	....	....	....	50	....	....	20
34	....	..	....	....	....	....	....	....	....	....	....	....	....	....	72	....	....	50
36	....	..	....	....	....	....	....	....	....	....	....	....	....	....	80	....	....	60
38	....	..	....	....	....	....	....	....	....	....	....	....	....	....	100	....	....	100

.026 pound of tin per base box is removed during a 30-minute process at 212° F.

The curves for the solution of iron, however, are not linear with time. During the early stages of storage, the solution of iron is inhibited. After this induction period, which differs for different steels, the rate of solution of iron is accelerated. Typical results are shown in Figure 3. These data indicate that hydrogen evolution results from the solution of iron and not from the solution of tin. Confirming evidence that tin dissolves in prunes without the
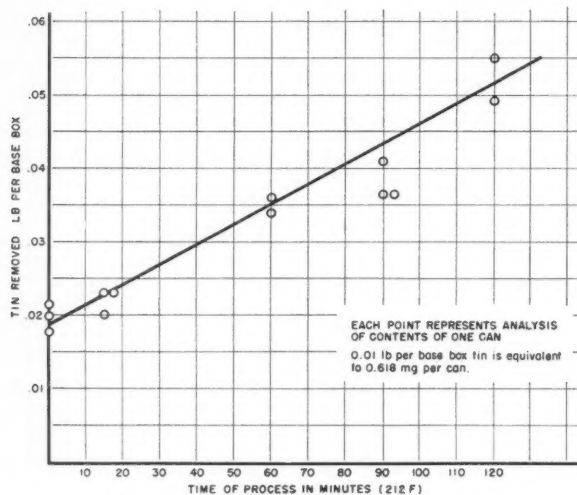
evolution of hydrogen was obtained by sealing a bar of pure tin in a glass jar of prunes. The tin dissolved and the prunes became bleached, but the jar did not lose its vacuum.

Effect of Tin Coating Weight on Failure Time

Although it has long been known in a general way that increasing the tin coating weight will increase the pack life of plain (unlacquered) cans,[5] it has been impossible to determine with accuracy the quantitative relationship between pack life and coating weight because of the non-uniform tin coating weights found on hot-dipped tin plate. The introduction of electrolytic tin plates on which the tin coating is very uni-

Figure 2—Rate of solution of tin during sterilization of cans. Media: Prunes in water.

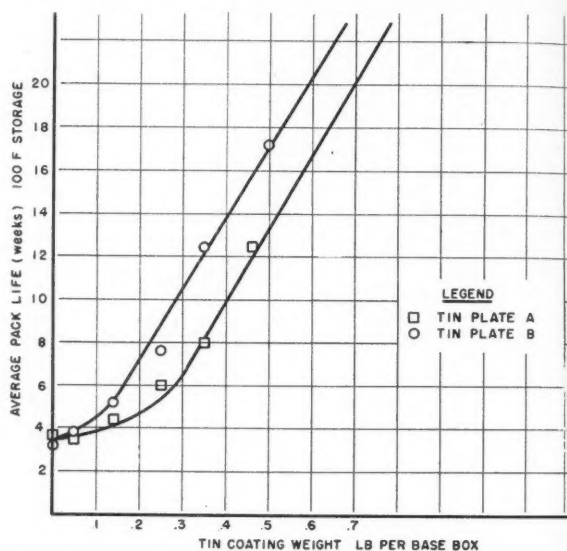Figure 4—Effect of tin coating weight on pack life. Coating varied by detinning to predetermined values.

Figure 3—Rate of solution of tin and iron during storage of cans at 100 degrees F. Media: Prunes in water.

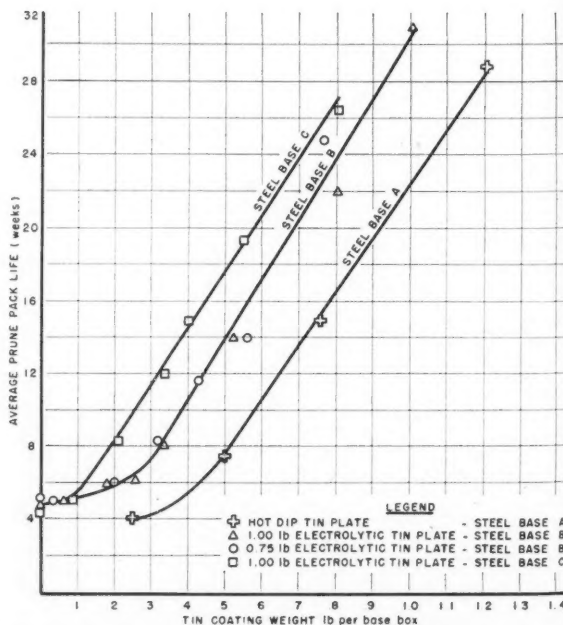Figure 5—Effect of tin coating weight on pack life, 100 degrees F storage. Coating varied by detinning to predetermined values.

form presented an opportunity to study the effect of tin coating weight more accurately.

Early in these investigations, it was observed that two samples of tin plate of comparable tin coating weight, but obtained from different steel bases, might exhibit different corrosion resistance. To study the effect of tin coating weight, it was therefore necessary to obtain samples in which the only variable was the weight of tin coating. This condition was met by detinning adjacent specimens of tin plate from single sheets of two steels, A and B, to predetermined tin coating weights so as to obtain uniform increments of coating weight. Test ends from the variously detinned coupons were then tested with prunes in the usual manner. Typical pack results for 0.50 pound electrolytic tin plate are shown in Figure 4. Pack results for tin plates with heavier tin coating weights, both electrolytic and hot-dipped, are shown in Figure 5.

Confirmation of the validity of the stripping procedure for studying the effect of tin coating weight variations on pack life was obtained on commercial tin plates. From three selected heats of steel, a group of coils was carried together through the various manufacturing processes (hot strip rolling, pickling, cold reduction, alkaline cleaning, annealing, temper rolling) to obtain black plate for tinning that would be as uniform as possible. Several coils each were electro-tinned to 0.10, 0.25, 0.50, 0.75 and 1.00 pound

per base box. Tinned samples were selected from the middle portion of each coil for testing. Usually forty-five test ends were stamped from the samples from each coil. Figure 6 shows the results obtained in the three experiments. The similarity of these curves with those in Figures 4 and 5 is apparent.
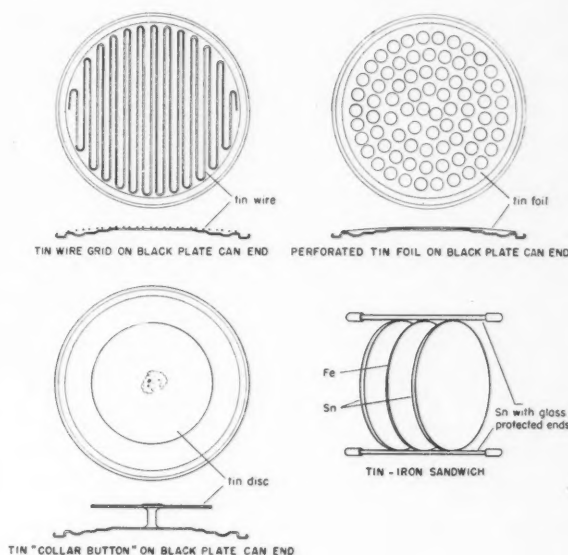

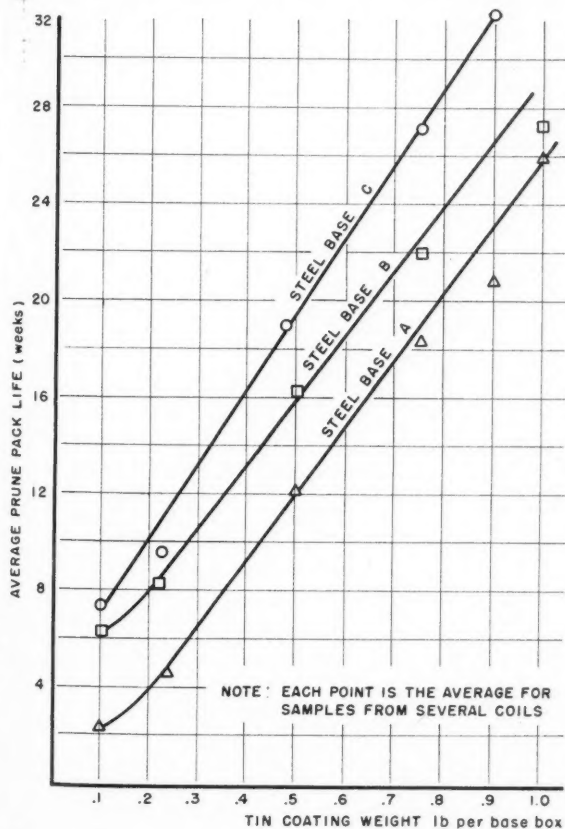Figure 7—Various types of tin-iron couples.

Figure 6—Effect of tin coating weight on pack life, 100 degrees F storage. Coating weight varied by plating separate coils to indicated tin coating weight.
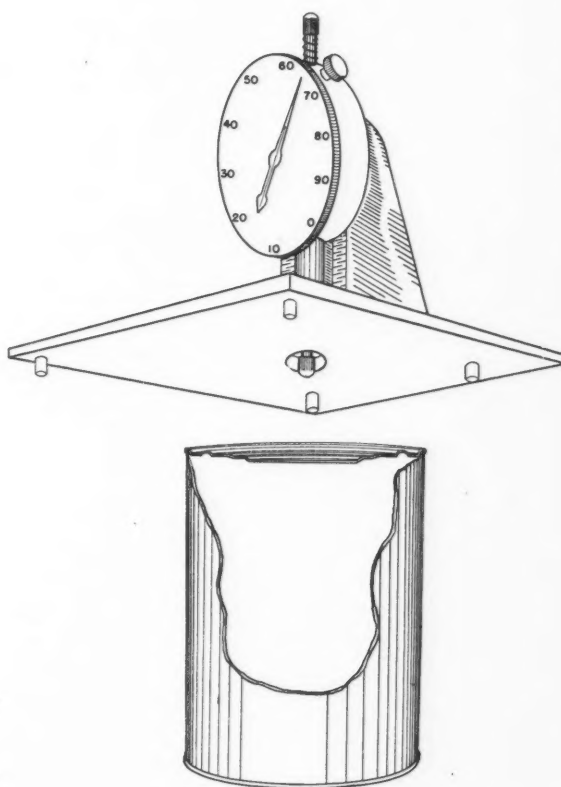

Figure 8—Dial gauge.

The effect of tin coating weight variation on pack life is influenced by the type of the steel base, at least with respect to prunes as a corroding medium. At zero tin coating weight, differences in the pack life of different steels, although measurable, are not very large in comparison to differences that exist at some finite tin coating weight, for example, 0.5 pound per base box. Above some minimum tin coating weight, which may be about 0.5 pound per base box or less, the increase in pack life per increment increase in tin coating weight will be the same for steels which have different resistances to corrosion.

Cathodic Protection of Iron by Tin

A logical explanation for the relation of tin coating weight and pack life is realized from a study of the cathodic protection of iron by tin. That tin is anodic to iron in fruits and fruit acids in the absence of air and thus accounts for the satisfactory performance of tin plate for food containers, has been reported by various investigators.[6, 7, 8, 9] Several experiments are described below which show that the degree of protection afforded by tin varies with the type of the steel base as well as with the food product. In these experiments, the rate of hydrogen evolution from tin-iron couples in food products was determined.

Test ends were prepared from black plate obtained by detinning samples of 0.50 pound electrolytic tin plate of known prune pack corrosion resistance. A solution of antimony trichloride in hydrochloric acid was used for detinning. Traces of adhering antimony were removed either by cathodic cleaning in dilute NaOH or by treatment with a boiling solution of 5 percent NaOH to which Na_2O_2 was added to maintain gas evolution. To the black plate ends, pure tin was attached in the form of: 1) tin wire grid, 2) perforated tin foil, or 3) "tin collar button." These are illustrated in Figure 7.

The progress of corrosion was followed by observing the change in the contour of the can end. The ends of a can behave like a diaphragm, deflecting with change in internal pressure. A dial depth gauge, shown in Figure 8, permits measurement of the difference in height of a can end, using the double seam as a reference. The deflection of one end of a can is proportional to the vacuum loss; as shown in Figure 9, it is evident that the relationship is nearly linear, and for the purpose of this discussion, a linear relationship is assumed. Corrosion rates are thus expressed in changes in dial reading per unit of time.

Tin Wire Grid on Black Plate* End

From 0.50 electrolytic tin plate having an average prune pack life of 17.5 weeks, black plate ends were obtained by detinning to the steel base. To these were fused strips of tin wire (0.050 inch diameter) spaced about ⅛ inch apart. The total surface area of the tin wire was calculated to be about 8.5 square inches, equal to that of the black plate. These ends were seamed to cans filled in one experiment with dried prunes and water, and in another with pureed frozen peaches. After processing to attain sterility,

---

* Black plate is a term used in the tin plate industry to denote the steel base used for making tin plate.

the cans were stored at 100° F. Periodically, the deflection of one can end was measured. Upon failure (when the can lost its vacuum), the contents were analyzed for tin and iron.

The rates of corrosion obtained in this test are shown in Figure 10. Unprotected black plate cans failed by hydrogen springer formation in from 3.0 to 3.5 weeks. Protected by the tin wire grids, black plate cans corroded at a greatly reduced rate, with average failure times of 63 and 72 weeks respectively, for peaches and prunes. The rate of vacuum loss for each product was constant with time. It is possible to predict the pack life in these tests once the vacuum loss curve has been determined, inasmuch as the intersection of the vacuum loss curve with a reading of 30 (equivalent to 18-inch vacuum loss, Figure 9) correlates very well with the average failure times observed. Commercial experience with plain tin plate containers is that peaches are considerably less corrosive than prunes. No explanation for the apparent similarity of corrosivity in the present tests can be given.

The quantity of tin dissolved from the tin wire for a given product was directly proportional to the time of failure. (See Figure 11.) Apparently, under these conditions, tin goes into solution without the evolution of hydrogen and the hydrogen is evolved by the solution of the iron. The iron values reported were not corrected for iron initially present in the product.

Black Plate Covered with Perforated Tin Foil

Black plate ends were covered with tin foil which was perforated with 5/16-inch holes so as to expose about 4.25 square inches of steel surface and an equivalent area of tin. Figure 12 shows the results obtained with two different tin plate steels. Steels A and B were the base metals of 0.50 pound electrolytic tin plate which had average prune pack failure times of 8.1 and 17.6 weeks respectively. The average

failure t
can be es
to reach
These fa
as that
failure t

These
forated
the corr
are expe
curring
on pack
and He
natural
meter,
of steel

Black

The c
perfora
prunes
tion of
extende
obtain
and are
tin to t
in faste
comme
and wa

Incre
area) t
base, b
steel B

Furt
the tin
in exp
fusing
to tin
inch. S
two ti
of pru
mined
a cons
with
button
sented
shows
steels
shown
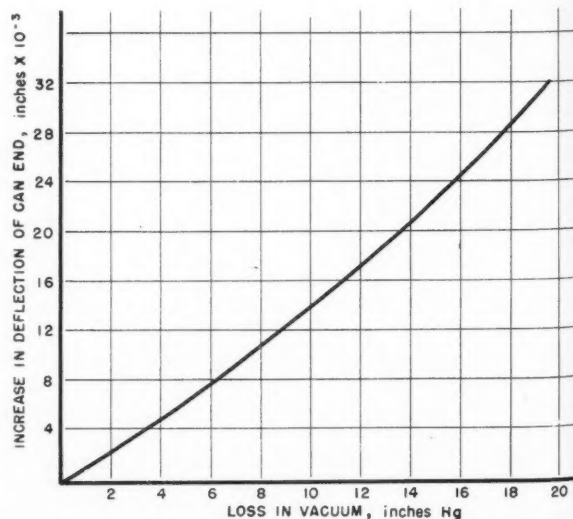
Figure 9—Relation of vacuum loss and change in deflection of can end 307-diameter cans.

failure times of the black plate protected by tin foil can be estimated from the vacuum loss curves. (Time to reach .030 inch change in deflection of can end.) These failure times are essentially in the same ratio as that for the 0.50 pound coated samples, but the failure times are about four times as long.

These tests with the tin wire grids and the perforated tin foil illustrate the ability of tin to inhibit the corrosion of iron, even though large areas of iron are exposed, and, hence, suggest that naturally occurring porosity of tin coatings has little or no effect on pack life of plain cans packed with prunes. Hoare and Hedges[10] estimate that the steel exposed by natural porosity is 0.67 to 0.798 square mm per square meter, which is infinitesimal compared to the areas of steel exposed in the above tests.

Black Plate Protected with Tin "Collar Buttons"

The experiments with the tin wire grids and the perforated tin foil on black plate ends tested with prunes resulted in low corrosion rates. The protection of the steel by the tin was too efficient, so that extended periods of time would be required to obtain significant results. Changing the geometry and area of the tin-steel couple, by fusing discs of tin to the black plate as shown in Figure 7, resulted in faster corrosion rates. Tests were conducted with commercial prune juice instead of with dried prunes and water. See Table II for the results of these tests.

Increasing the area of exposed tin (total surface area) resulted in increased protection for the steel base, but the increase in protection was greater for steel B than for steel A. See Figure 13.

Further evidence of the effect of the geometry of the tin-steel couple on corrosion rate was obtained in experiments in which couples were formed by fusing alternate 4-square-inch discs of tin and steel to tin rods so as to obtain a separation of about ¼ inch. Single couples consisting of a steel disc between two tin discs were enclosed in full-enamel-lined cans of prune juice and the progress of corrosion determined in the usual manner. Instead of corroding at a constant rate, as did the black plate ends protected with tin wire, perforated tin foil or tin "collar buttons," these couples corroded at a rate represented by the parabolic equation $y = kt^{1/2}$. Figure 14 shows the corrosion curves obtained for the two steels (A) and (B). These are the same steels as shown in Figure 12 and Figure 13.
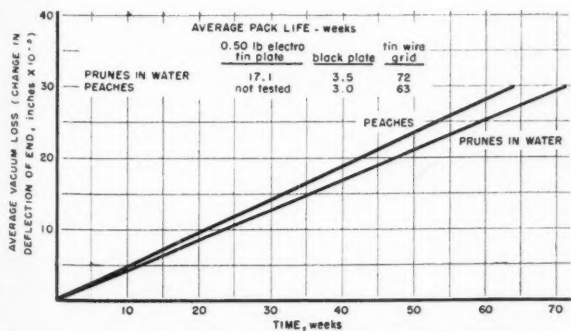
TABLE II
Corrosion rate of tin "collar button" protected black plate

Steel Base	Average Pack Life of 0.50 Coated Plate	Corrosion Rates* Dial Change In. x 10⁻³ per Week Diameter of Tin Disc		
		$^{15}/_{16}$ in.	$1^{15}/_{16}$ in.	$2^{3}/_{4}$ in.
A	8.1 weeks	19.5	7.3	4.6
B	17.6 weeks	8.0	2.1	1.1

* Constant rate reached after 1.5 weeks storage (The rates for the tin foil protected black plates were calculated from the curves in Figure 12—(A) 0.9 and (B) 0.4 respectively.)
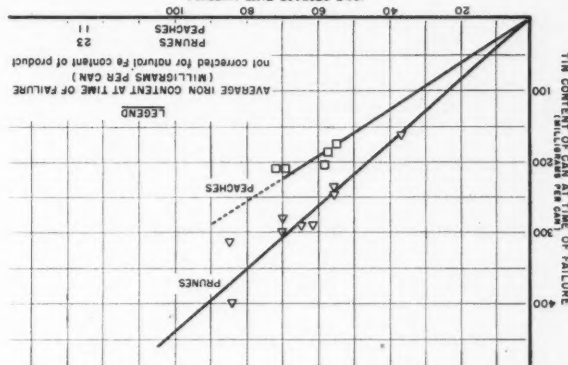
Figure 11—Rate of solution of tin and iron during storage of cans at 100 degrees F protected with tin wire grid.
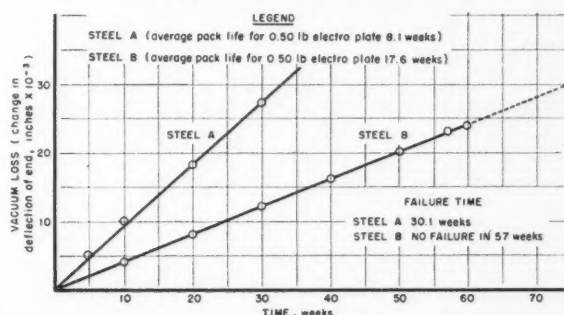
Figure 12—Rate of vacuum loss in cans during storage at 100 degrees F. Cans with black plate ends protected by perforated tinfoil. Media: Prunes in water.

Figure 13—Effect of increasing the area of exposed tin in cans on corrosion resistance index during storage at 100 degrees F. Black plate can ends protected by tin collar buttons. Media: Commercial prune juice.

Figure 10—Vacuum loss in cans, 100 degrees F storage. Black plate ends protected with tin wire grid.

The time to produce a given vacuum loss is proportional to the function $\frac{(1)}{(k)^2}$ where "k" is the slope of the straight line obtained from a plot of the vacuum loss and the square root of time. The steel bases from five lots of 0.50 pound electrolytic tin plate, which had prune pack lives ranging from 8 to 22.8 weeks, were tested in the form o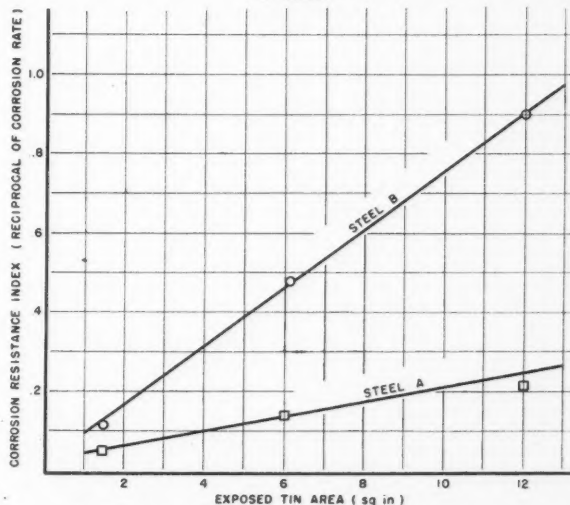f tin-steel couples. The data are shown in Figure 15. The tin-steel couple corrosion data are expressed as the function $\frac{(1)}{(k)^2}$ and the pack life data are expressed in weeks. The tin plate steels are rated in the same order by the tin-steel couple test as the respective tin plates are evaluated by the prune pack, although the relation is not exactly linear.
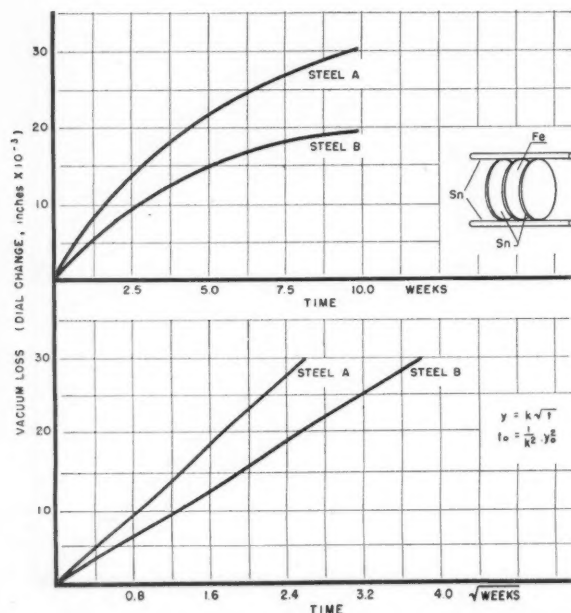

Figure 14—Rate of corrosion of tin-iron couples in canned commercial prune juice during storage at 100 degrees F.
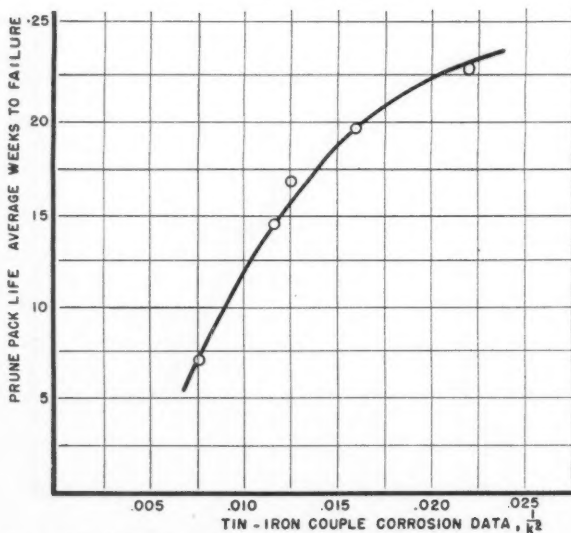

Figure 15—Correlation of tin-steel couple corrosion data with prune pack life of 0.50-lb. electro tin plate cans.

Solution potential measurements of the tin-steel couples in prune juice in the absence of air have been made, but they are very erratic. The trend is for higher values (50 mv) to be associated with type A steel and low values (10 mv) to be associated with type B steel. These investigations are being actively pursued.

Evaluation of Tin Plate Steel Base by Means of Prune Juice Corrosion Tests

Hoar, Morris and Adam[11] reported that weight losses sustained by untinned tin plate steel base specimens immersed in actual fruit juice in the presence of air gave poor correlation with the rate of hydrogen-swell formation within the can. Their experimental procedure consisted of immersing 5 x 1 cm flat specimens of steel base in 15 ml of sterilized fruit juice in a test tube protected with a cotton wool plug. Loss in weight was determined after 72 hours at 25° C. The authors concluded that the inability to duplicate the essentially oxygen-free conditions within the can probably caused the failure to correlate with can performance.

Tests in this laboratory indicate a high degree of correlation between corrosion of untinned tin plate steel base in prune juice and the rate of hydrogen springer formation of tin plate containers when the untinned steel samples are corroded in the absence of air. Tin plate of known pack life was detinned as described before. Number 2 can ends were fabricated from the black plate obtained to form one end of the test cans. The rate of hydrogen evolution was found to be linear with time as measured by vacuum loss. Figure 16 illustrates the correlation obtained with twenty-six different lots of tin plates. A more comprehensive treatment of this method of testing will be the subject of another paper.

Summary

Evidence has been cited which indicates that, in prunes at least, the hydrogen evolution within a tin container is controlled by the rate of solution of the
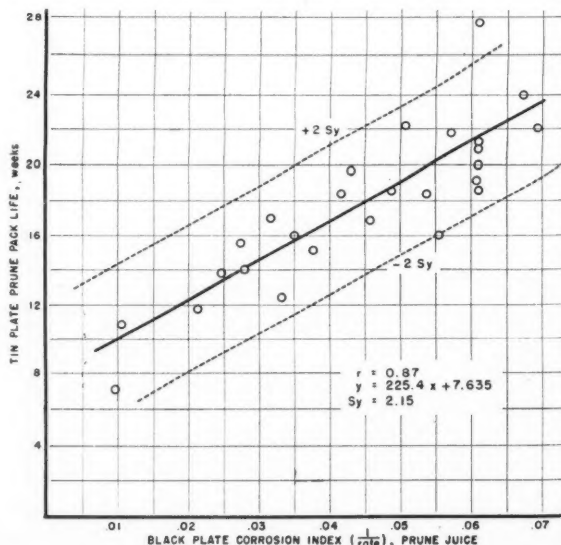

Figure 16—Correlation of prune pack life with black plate corrosion rate.

iron. Tin goes into solution in prunes without the evolution of hydrogen.

The direct relation of tin coating weight to the corrosion resistance of tin plate in prunes has been demonstrated for several types of steel.

Tests are reported which illustrate the high degree of protection afforded the steel by the tin member of a tin-steel couple. These tests indicate that the significance of porosity of tin coating on the failure rate of plain cans is slight.

Several types of pack tests to evaluate the characteristics of various steels, with respect to resistance to corrosion in prunes, have been studied. These include tin-steel couples of various geometric design and black plate prune juice tests. These tests illustrate the cathodic protection afforded steel by tin and also indicate that quality of the steel base is related to the corrosion resistance of the tin plate manufactured from it.

References

1. R. H. Lueck and K. W. Brighton. "Behavior of Foods in War Time Cans," *Canned Food Packer*, **5**, 6, 17-25; 7, 18-21, 23, 25, 29 (1948).
2. W. G. Cass. "Recent Developments in the Use of Electrolytic Tin Plate and Phosphated Black Plate," *Sheet Metal Ind.*, **23**, 1917-1918 (1946).
3. W. E. Hoare. "Electro Tin Plate in the United States" —Spring, 1948. Published by the *Iron and Coal Trade Review*, 49 Wellington Street, Strand, London, England, WC 2.
4. R. R. Hartwell. "Corrosion Resistance of Tin Plate. Influence of Steel Base Composition on Service Life of Tin Plate Containers," National Metals Congress at Cleveland, 1940, American Society for Metals, Preprint 1944.
5. "Canned Food Containers," A study with special reference to the influence of the steel base on resistance to perforation. National Canners Association Research Laboratory, Bulletin 22L, 1923.
6. C. L. Mantell and W. G. King. "Reversed Potentials in the Corrosion of Tin Plate"—*American Electrochemical Society*, **53**, 435 (1927).
7. R. H. Lueck and H. T. Blair. "Corrosion in Tin Cans." Electrochemical Relations of Tin and Iron, *Trans. AES*, **54**, 257 (1928).
8. T. N. Morris and J. M. Bryan. "Corrosion of Tin Plate Containers by Food Products"—Food Investigation, Special Report No. 40, 1931.
9. E. F. Kohman and N. H. Sanborn. "Factors Affecting Relative Potentials of Tin and Iron," *Ind. and Eng. Chem.*, **20**, 1373, (1928) Dec.
10. W. E. Hoare and E. S. Hedges. "Tin Plate"—Published by Edward Arnold and Company, London, England (1945).
11. T. P. Hoar, N. H. Morris and W. B. Adam. "The Influence of the Steel Base Composition on the Rate of Formation of Hydrogen Swells in Canned Fruit Tin Plate Containers"—Part II, *Journal Iron and Steel Institute II*, **1941**, 133-155.

NACE REPRINT PRACTICE

Application of Corrosion - Resisting Materials To Railroad Electrical Construction ★

By H. F. BROWN**

Introduction

IN THE DECADE between 1905 and 1915 a number of steam railways in the United States and abroad installed electrification for certain important sections of their lines using an overhead contact system. On those lines using high voltage, where current carrying capacity was not of such importance as on lower voltage lines, steel was used for the supporting messenger of the cantenary contact system, and in some cases, even for the contact wire itself, with suspension hardware and details also made of ferrous materials.

When steam locomotion was continued on some lines electrical equipment was subjected to the exhaust steam as well as vapors and gases produced by combustion of bituminous coal.

Within a very few years after electrification was begun, it was found that deterioration of the ferrous materials was very rapid, even though they had been heavily galvanized; and the maintenance of such construction indicated that other materials, or other modes of protection, would have to be used if reasonably long life was to be expected.

Work Done Prior to Formation of AAR Committee

Tests on Protective Coatings.

Effect of smoke and gases on various kinds of protective coatings, including galvanizing, Sherardizing, lead coatings, and copper coatings, together with various kinds of paint and paint vehicles were studied under severe conditions. Specimens were hung in smoke stack of round house where they were subjected to nearly continuous atmospheres of hot smoke, gas and steam:

The following conclusions were drawn:

1. Hot dipped galvanizing was in general superior to Sherardizing, notably superior to lead coatings, and in general lasted about one month in the stack as compared to from one to two years in service over steam operated tracks.
2. Paints having a vehicle which oxidized were in general superior to those (on the market in 1921) having a vehicle which evaporated. Good painting lasted about as long as galvanizing in this atmosphere.
3. Copper coated steel wires resisted corrosion for a while, but corroded very rapidly in spots if flaws or cracks developed in their outer coating.

Abstract

The Association of American Railroads, through the Electrical Section of the Engineering Division have had a committee investigating the relative corrosion of ferrous and non-ferrous alloys in smoky atmospheres ever since 1930. That committee made installations of various kinds of alloys in a freight terminal yard at Lamberts Point, Norfolk, and in a tunnel in Welch, West Virginia, both located on the N&W Railroad. These installations were subjected to steam locomotive exhaust and gasses, and in the case of the Lambert Point installation, to dampness and fog from the seacoast. A third installation of identical materials was made in one of the smoke stacks of a steam locomotive round house on the New Haven Railroad at Cedar Hill, Connecticut. All of these materials were exposed for more than five years, and were examined periodically throughout the exposure period, and reported to the Electrical Section, AAR. This article summarizes the work done by this committee, which was an attempt to find the most economical alloys to be used in railroad overhead contact systems.

Tests on Metallic Materials Conducted by Fred Wolf of Ohio Brass Company.[1, 2]

Selected ferrous and non-ferrous metals were tested under service smoke conditions on two Eastern electrified steam railroads and in a railroad roundhouse smoke stack in Mansfield, Ohio. These tests were based on loss of weight per square inch of original surface per year.

The conclusions from these tests are reported.

A paper[3] titled "The Relative Corrosion of Ferrous and Non-Ferrous Alloys in Smoky Atmospheres" by H. F. Brown reviews work done by early railway technical committees.

Research by the Electrical Section, Engineering Division, AAR

General Program.

Committee XVI, which was appointed in 1929 and which later became No. 13, set up a test program to study The Application of Corrosion-Resisting Materials to Railroad Electrical Construction in three locations:

1. Roundhouse smoke stack at New Haven on the New York, New Haven and Hartford Railroad.
2. Hemphill Tunnel at Welch, West Virginia on the Norfolk and Western Railway.
3. Lambert Point Coal Pier at Norfolk, Virginia, on the Norfolk and Western Railway.
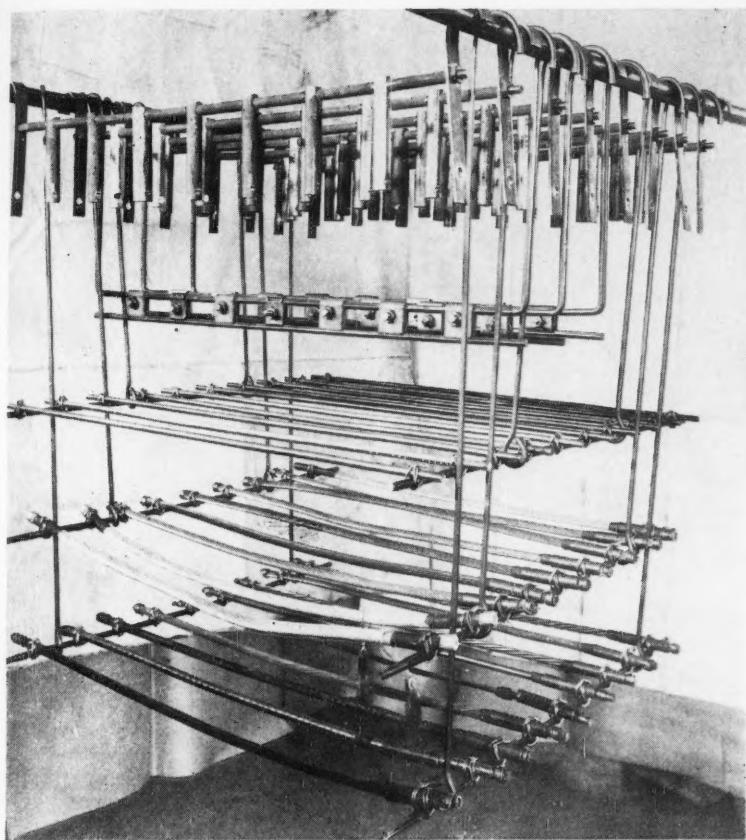
Figure 1—Assembly of material for AAR test in Cedar Hill stack.

Manufacturers of alloys and catenary line materials were invited to submit samples for corrosion tests. The following specimens were received from twenty-six companies:

57 Round bars, 1″ x 6″ (drawn).
20 Trolley clips.
 8 Carriage bolts and nuts, ½″ x 1¼″.
10 Samples 4/0 grooved trolley wire.
17 Samples stranded cable.

Complete report gives chemical and physical properties and other pertinent data on these materials.

All samples were weighed.

Installation of Test Specimens

Cedar Hill Test Station

One set of all samples was assembled as shown in Figure 1 and hung in an open smokestack at the roundhouse at Cedar Hill, New Haven, Connecticut, on June 3, 1930. This location gave very severe exposure to smoke combined with weather conditions, including salt fog.

Hemphill Tunnel Test Station

Set of test specimens was installed on January 22, 1931, in center of Hemphill tunnel (Figures 2 and 3) which is a double track, con-crete lined, straight tunnel about one-quarter mile long on the electrified section of the Norfolk and Western Railway near Welch, West Virginia. There was considerable steam operation through this tunnel so that specimens were subjected to the corrosive effects of locomotive smoke, exhaust gases and steam. They were protected from the weather by being in the tunnel.

Lambert Point Test Station

A set of specimens was installed at Lambert Point (Figure 4), Hampton Roads, Virginia, on January 21, 1932, over a steam operated switching lead in the N. & W. Railway yard. Samples were exposed to severe service conditions and to salt water fog.

Inspection

Specimens were inspected annually.

The one-inch round samples at Cedar Hill were removed, cleaned and weighed each year for four consecutive years, being finally removed in July, 1934. The condition of the strand samples, clips and trolley wire specimens at Cedar Hill was such that they were removed on June 8, 1938, for final cleaning and weighing.

Hemphill tunnel specimens were removed, cleaned and weighed at end of five years.

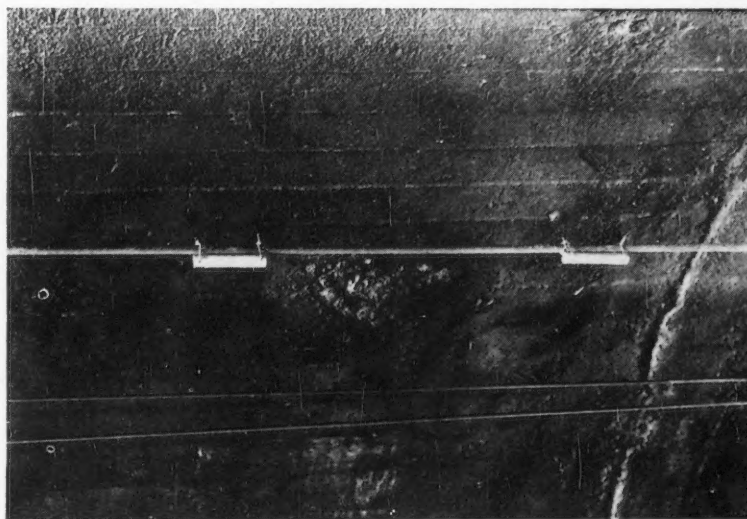Lambert Point specimens were removed and cleaned and weighed at end of eight years.

Figure 2—One-inch round samples installed in Hemphill Tunnel, Norfolk and Western Railway, AAR tests.
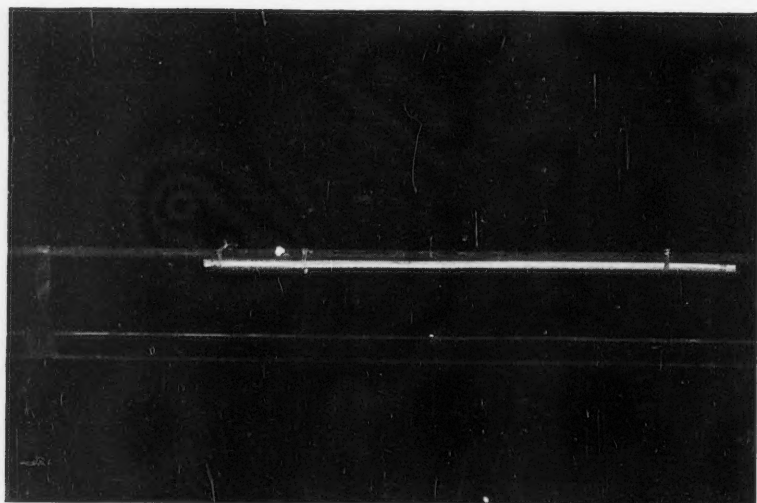
Figure 3—Strand samples installed in Hemphill tunnel, Norfolk and Western Railway, AAR tests.
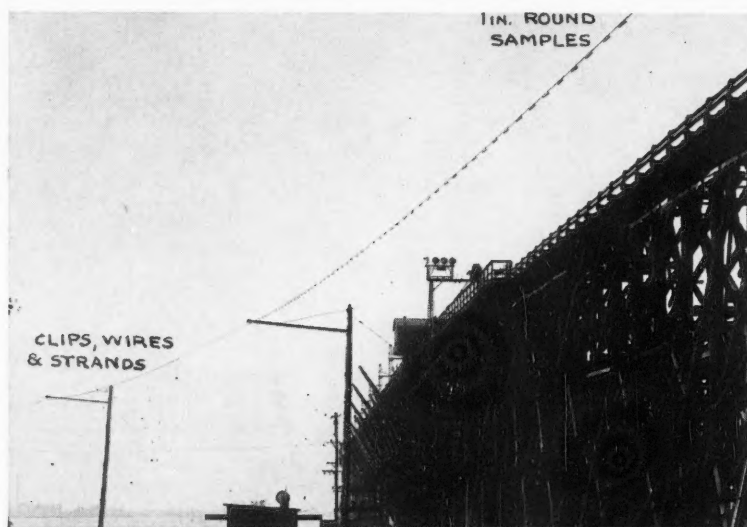

Figure 4—Samples installed at Lambert Point, Norfolk and Western Railway, AAR tests.

The Lambert Point test represented about average corrosive conditions over steam-operated railroad tracks where moderate steam service is maintained, combined with the damp climatic conditions along the coast.

In general, materials which showed relatively good corrosion resistance in the accelerated tests at Cedar Hill also showed relatively good corrosion resistance in the service tests at Hemphill tunnel and Lambert Point. However, it would be impossible to predict accurately the corrosion loss of the various materials in service from accelerated tests in a smokestack, because the depth of loss was not proportional for the various materials tested. For example, the depth of loss of sample 0403 of 17 ST aluminum at Lambert Point was 5.7 percent of the loss at Cedar Hill, while for Sample 3201 of 18-8 Stainless Steel it was only 0.086 percent of the loss at Cedar Hill.

In general, all the metals commonly used in industry will corrode to a greater or lesser degree in smoky atmospheres. The rate of corrosion is much greater where soot and other tarry products of combustion are concentrated enough to form adherent coatings which cannot be removed by rain, wind or other mechanical agencies, probably because of the highly corrosive sulfur compounds usually present with such deposits, and also because of the highly cathodic position, of carbon to all of the other metals, with the exception of tungsten, molybdenum, vanadium and chromium. This fact immediately emphasizes the value of protective coatings which can be developed to be inert enough to the highly active corroding agencies of this kind, provided they can be economically applied and maintained. This remains a fertile field for further investigations.

All the tests seem to confirm the fact than in general, the non-ferrous metals, especially copper and alloys having a high copper content, are more resistant to this form of corrosion than the ferrous alloys commonly used, although some of the nickel-chrome ferrous alloys show nearly the same low losses as the copper alloys.

In the Non-Ferrous Group:

1. The alloys of high copper content show, in general, the least amount of loss, with best superficial appearance.

Results

Complete report gives detailed information on final inspection before and after cleaning together with weight loss and photographs of cleaned specimens at each test location. Figures 5 and 6 showing the one-inch round specimens at end of four years at Cedar Hill Test Station are included here as examples of photographic data which show corrosion patterns.

The weight loss data and penetration for the one-inch round specimens for all three locations are summarized in Table S-I and S-II.

Conclusions Derived From Tests

The Cedar Hill test was an accelerated test in which the corrosive conditions were much worse than the usual conditions over steam-operated railroad tracks.

The Hemphill tunnel test represented corrosive conditions existing under the most severe service conditions on a steam-operated railroad.

Figure 5—Appearance of 1-inch round ferrous samples at end of four years in smoke stack, AAR tests.

resistant than alloys with a higher tin content. (Sample 5202 with 9.9 percent tin.)

6. There was little difference between the performance of the copper-nickel alloys with high copper content (Samples 0502, 3001, 4501) as compared with those having high nickel content (Sample 4001) in any of the tests.

7. Aluminum bronzes, especially the cast samples, seemed to be in general somewhat inferior to the other copper alloys. Even with more favorable weight loss, the appearance was inferior, with noticeable roughness and pitting. Sample 1101 of aluminum bronze containing 22.5 percent zinc and 6.5 percent of aluminum had a very large loss.

8. Aluminum showed the greatest losses of all the non-ferrous materials in all the tests. They were comparable to the losses of plain carbon steel in the round samples. The behavior of the clip and strand samples was equally disappointing.

In the Ferrous Group:

1. The cast samples have a greater resistance to this form of corrosion than the rolled or drawn samples of similar analysis, malleable iron occupying a position somewhere between the plain steels and the chrome-nickel steels.

2. High silicon cast iron is extremely resistant to smoke corrosion, but is too hard and too brittle to be used for overhead line material or parts requiring machining.

3. The addition of copper to plain steels (so-called copper bearing steels) or to wrought iron, increases its resistance to smoke corrosion somewhat, but not to the extent found under other corrosive conditions. Copper bearing wrought iron showed losses comparable with ungalvanized malleable iron—somewhat greater in the Hemphill tunnel test, and somewhat less in the Lambert Point test. Sample 2201 of ungalvanized copper-bearing steel had somewhat lower loss than plain low carbon steel. No great difference could be determined in the scale formation and adherence, as between the plain irons and steels, and those having a copper content. Sample 4201 of ungalvanized malleable iron had much lower loss than plain low carbon steel.

2. The simpler alloys are in general superior to the more complex.

3. Rolled or drawn samples showed somewhat more resistance to smoke corrosion than the cast samples of similar analysis.

4. Zinc up to about 20 percent in a high copper alloy (Sample 0030) does not adversely affect its resistance to this form of corrosion. Brasses containing more than 20 percent of zinc are not satisfactory where subjected to locomotive smoke. Sample 5401 of leaded brass containing 33.73 percent of zinc, and sample 5402 of Muntz metal containing 40.7 percent of zinc, had a dezincified layer, which had very little strength.

5. Tin up to 10 percent seemed to have little effect on the resistance of the alloy to corrosion in the Cedar Hill test. Some alloys with less than 2 percent (Sample 2301) of tin seemed to be more

Of interest in connection with this subject is a test made on two suspension insulator caps exposed in the

Cedar Hill stack for four years. One cap was of galvanized drop forged copper bearing steel, the other was of galvanized malleable iron. The interior of each cap was filled with cement to confine the corrosion to the surfaces normally exposed. At the end of four years the copper bearing steel cap had lost 42.6 percent of its original weight, while the malleable iron had lost 30.6 percent of its weight. In neither case did the corrosion seriously affect the strength of the remaining metal.

4. The superiority of wrought iron or "ingot" iron to steel for resistance to smoke corrosion was negative in all tests; this material apparently has as large a percent loss as any of the materials in all tests even with a small copper content. Sample 5302 of wrought iron was badly pitted and had the greatest loss of any of the samples.

5. Galvanizing, as a means of protection against smoke corrosion, is of very short life under severe corrosive conditions. The galvanized samples at Lambert Point had considerably lower loss than the ungalvanized samples, but there was very little difference between the galvanized and ungalvanized samples at Hemphill tunnel and less at Cedar Hill.

6. The stainless steels tested have a resistance to smoke corrosion comparable with some of the non-ferrous alloys. Cast samples 3501, 3502, 3503 and 3504 of chrome-nickel steel had very little loss, but these alloys are intended for high temperature use, and are very expensive.

The resistance to corrosion of most of these alloys is partly due to surface treatment, i.e., removal of mill scale, heat treatment, and polishing. The corrosion rate is very low at the start on this material with polished surfaces, but once corrosion has started, or if carbon deposits adhere, a scale is formed, which is self-continuing. It is believed that this accounts for the greater loss in the samples of these materials at Cedar Hill than in those at Hemphill tunnel or Lambert Point.

The rate of corrosion, once started, is accelerated in contact with dissimilar metals, especially copper.

The tests indicated that the chrome-nickel steels had somewhat lower losses than the chrome steels. There was, in general, a greater amount of pitting with these materials than with the non-ferrous alloys, and greater loss of sharp edges in the clip samples. Sample 4002 of cast copper nickel steel had a rela-

Figure 6—Appearance of 1-inch round non-ferrous samples at end of four years in smoke stack, AAR tests.

tively small loss in the Cedar Hill test, but had a relatively large loss in the Hemphill tunnel and Lambert Point tests.

Particular attention is called to the chrome-nickel-molybdenum sample 1501 installed at Lambert Point and Hemphill tunnel, and to strand sample 1551 installed in Hemphill tunnel, all of which had relatively little evidence of corrosion and practically no loss in weight. It is assumed that this is due to the molybdenum content.

Strand Samples

The loss in weight of the strand samples at the three test locations are not comparable because of their difference in size and construction. The appearance of the samples gives the best idea of their corrosion resistance.
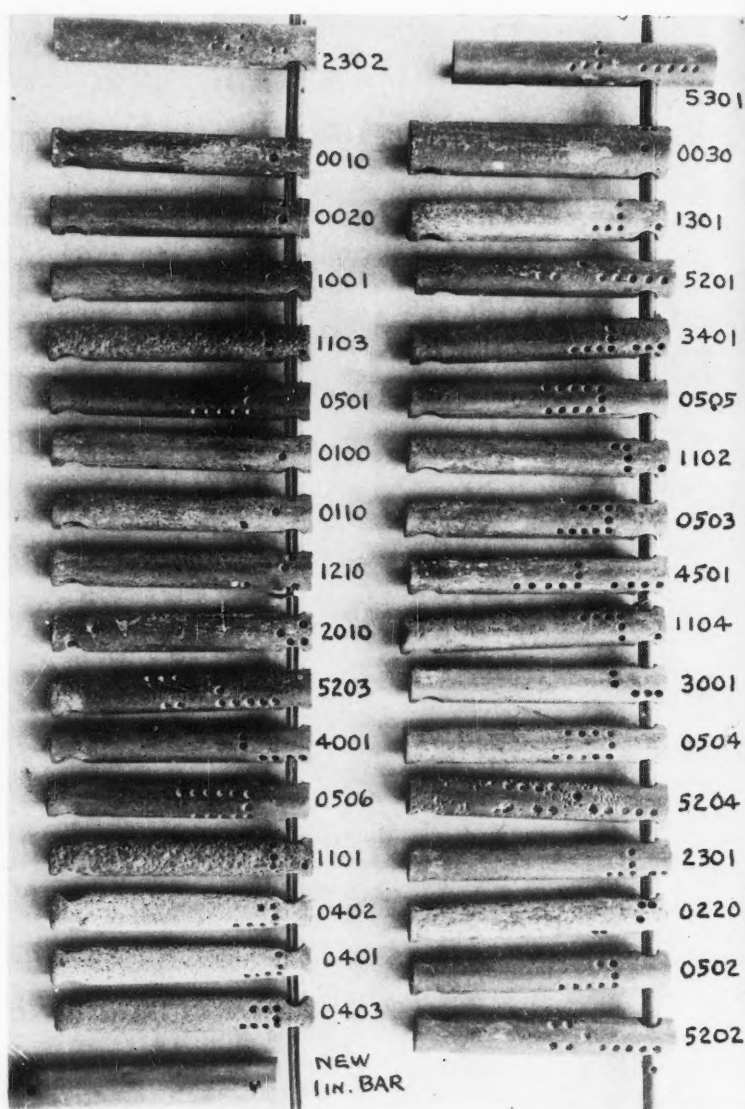
TABLE S-I

Summary of Test of 1 Inch Round Samples 6 Inches Long at Cedar Hill, Hemphill Tunnel, and Lambert Point.

NON-FERROUS ALLOYS

Code No.	Kind of Alloy	Loss Per Year in %			Depth Of Loss Per Yr.in .001"		
		Cedar Hill	Hemphill Tunnel	Lambert Point	Cedar Hill	Hemphill Tunnel	Lambert Point
0401	Cond'r. Aluminum	8.83	1.66	0.28	19.90	3.90	0.64
0402	"3 SH" Aluminum	6.63	2.04	0.26	14.80	4.80	0.61
0403	"17 ST" Aluminum	7.99	1.68	0.45	17.90	3.96	1.03
0030	Brass	5.10	0.18	0.07	14.70	0.50	0.21
0504	"	6.16	0.26	0.10	13.82	0.60	0.23
5401	Leaded Brass	(1)	1.60(3)	0.33	(1)	3.60(3)	0.72(3)
5402	Muntz Metal	(1)	2.88(3)	0.37	(1)	6.60(3)	0.83(3)
0010	Bronze	6.84	0.28	0.063	15.30	0.64	0.15
0020	"	5.84	0.28	0.05	13.00	0.64	0.13
0100	"	7.12	0.32	0.11	16.00	0.74	0.25
0110	"	7.18	0.28	0.05	16.10	0.64	0.13
0220	"	6.54	0.22	0.11	14.70	0.50	0.26
1001	"	10.20	0.26	0.075	23.10	0.60	0.18
2010	"	6.56	0.30	0.05	14.72	0.68	0.13
2301	"	6.38	0.20	0.05	14.20	0.46	0.13
0503	Aluminum Bronze	6.05	0.32	0.075	13.60	0.74	0.16
1101	" "	9.20	2.70	0.26	20.80	6.46	0.61
1102	" "	6.00	0.38	0.063	13.50	0.86	0.15
1103	" "	6.47	1.84	0.063	14.67	4.34	0.15
1104	" "	5.76	0.44	0.05	12.80	1.00	0.10
1301	" "	5.28	0.34	0.075	11.70	0.78	0.16
3401	" "	5.75	0.34	0.05	12.78	0.78	0.13
5404	Nickel Alum.Bronze	(1)	0.32	0.14	(1)	0.70	0.30
5405	" " "	(1)	0.40	0.108	(1)	0.88	0.24
0502	Nickel Bronze	6.63	0.20	0.063	15.00	0.46	0.15
3001	"	6.17	0.38	0.063	13.90	0.86	0.13
4501	"	6.15	0.48	0.125	13.80	1.10	0.28
1210	Phosphor Bronze	7.27	0.20	0.075	16.20	0.46	0.16
5201	" "	3.83	0.24	0.075	8.60	0.54	0.16
5202	" "	4.52	0.26	0.075	10.00	0.60	0.16
5203	" "	4.61	0.44	0.063	10.30	1.00	0.14
5204	" "	3.98	0.38	0.088	8.90	0.86	0.18
0505	Copper	6.15	0.20	0.063	13.80	0.46	0.14
0501	Mang.Sil.Bronze	7.04	0.22	0.05	15.80	0.50	0.13
0506	" "	7.56	0.28	0.05	17.00	0.64	0.13
4001	Copper Nickel Alloy	7.04	0.36	0.063	15.80	0.82	0.15
5301	Silicon Bronze	(1)	0.16	0.106	(1)	0.35	0.23
5403	"	(1)	0.28	0.097	(1)	0.62	0.22
5501		(1)	0.30	(2)	(1)	0.66	(2)
5502		(1)	0.30	(2)	(1)	0.66	(2)
4003	Chrome Nickel Alloy	(1)	0.31	0.019	(1)	0.71	0.04
2302	Sil.Alum.Bronze	(1)	0.38	0.069	(1)	0.86	0.14

(1) Sample not received in time for test.
(2) Original weight lost.
(3) After dezincified layer had been removed.

TABLE S-II

Summary of Test of 1 Inch Round Samples 6 Inches Long at Cedar Hill, Hemphill Tunnel, and Lambert Point.

FERROUS ALLOYS

Code No.	Kind of Alloy	Loss Per Year in %			Depth of Loss Per Yr.in .001"		
		Cedar Hill	Hemphill Tunnel	Lambert Point	Cedar Hill	Hemphill Tunnel	Lambert Point
4201	Malleable Iron (Blk)	9.58	3.60	0.525	21.70	8.70	1.19
4202	" " (Galv.)	8.24	1.96	0.188	18.50	4.60	0.43
1401	Ingot Iron (Galv.)	11.73	6.50	0.31	26.80	16.50	0.73
1402	" " (Black)	13.38	7.74	1.09	30.50	20.10	2.56
5302	Wrought Iron	(1)	8.40	1.63	(1)	21.20	3.73
2101	Silicon Iron	3.66	0.16	0.025	8.20	0.36	0.06
2203	Carbon Steel (Blk.)	12.75	6.38	0.76	29.70	16.20	1.79
2204	" " (Galv.)	12.88	4.80	0.14	30.00	11.80	0.29
5101	Soft Commercial Steel	13.61	6.86	1.16	31.20	17.50	2.75
2201	Copper B'r'g.Stl.(Blk)	11.17	6.28	0.63	25.70	15.90	1.44
2202	" " " (Galv)	10.13	4.66	0.14	23.40	11.46	0.31
2501	" " Iron	8.98	5.52	0.40	20.30	13.80	0.94
0310	Chrome Steel	6.40	0.28	0.031	14.20	0.64	0.06
2401	" "	6.55	0.26	0.006	14.80	0.60	0.01
2403	" "	6.87	0.18	0.006	15.40	0.42	0.01
2405	" "	7.00	1.32	0.088	15.70	3.06	0.19
2502	" "	6.92	0.42	0.038	15.60	0.94	0.08
4301	" "	5.24	0.40	0.063	11.50	0.92	0.15
4303	" "	6.07	0.06	0.038	15.40	0.14	0.09
1502	Chrome Nickel Steel	(1)	0.094	0.000	(1)	0.20	0.00
2404	" " "	5.93	0.24	0.004	13.20	0.54	0.01
3201	" " "	5.44	0.006	0.006	12.20	Very slight	0.01
3301	" " "	6.71	0.96	0.05	15.10	2.20	0.13
3302	" " "	6.29	0.40	0.025	14.00	0.92	0.06
4101	" " "	5.96	0.002	0.013	13.40	Very slight	0.01
4302	" " "	5.25	0.22	0.038	11.55	0.50	0.09
4304	" " "	6.19	0.26	0.025	13.95	0.60	0.06
1501	Chr.Nickel Moly.Steel	(1)	0.046	0.000	(1)	0.10	0.00
1503	Chrome Copper Steel	(1)	(2)	(2)	(1)	(2)	(2)
3501	Chr.Nickel Cast Steel	4.64	1.28	0.038	10.40	3.00	0.10
3502	Chr.Nickel Cast Steel	4.73	0.50	0.038	10.70	1.16	0.10
3503	Chr.Nickel Cast Steel	4.83	0.62	0.05	10.90	1.42	0.13
3504	Chr.Nickel Cast Steel	4.10	0.36	0.025	9.50	0.82	0.05
4002	Copper Ni. Cast Steel	3.09	0.92	0.013	6.90	2.10	0.04

(1) Sample not received in time for test.
(2) Sample lost.

In general their performance may be summed up as follows:

1. Aluminum is not a satisfactory material for stranded conductors over a steam railroad.
2. Copper and bronze give very satisfactory performances, although some of the bronzes have developed season cracking in railroad service.
3. Copper-covered steel (copper-clad) will give excellent performance in service where smoke conditions are not too severe. If directly over steam locomotive exhaust, an outer layer of copper or bronze wires, with an inner core of copper-covered wires, will have satisfactory corrosion-resisting ability.
4. Stainless steel strands give promise of good resistance to smoke corrosion in service. It will be noted, however, that season-cracking was experienced with some of this earlier material.

The superior performance in Hemphill tunnel of the chrome-nickel Sample 1551, containing molybdenum is of particular interest.

While the results of these tests may seem discouraging to the manufacturers of some of the materials tested by the AAR committee, it is to be remembered that this type of corrosion in its intensive form is probably one of the most destructive of all the corrosion processes going on in modern industry.

It is not contended that the smokestack tests will show the exact relative resistance to ordinary atmospheric corrosion of the various alloys tested, but is believed that such tests will, in a short time, show the probable ultimate behavior of most of these materials in service where smoke is to be an important external factor.

References

1. F. L. Wolf. Technical Publication No. 293, AIMME.
2. F. L. Wolf and L. A. Meisse. "Corrosion," presented to ASTM. June, 1931.
3. H. F. Brown. "The Relative Corrosion of Ferrous and Non-Ferrous Alloys in Smoky Atmospheres." Report, Power Committee No. 12, American Electric Railway Association (now American Transit Association) 1934.

NACE TECHNICAL PRACTICES COMMITTEE REPORTS

Condensation of First Interim Report on Galvanic Anode Tests of Sub Committee TP-2—*Galvanic Anodes for Cathodic Protection* *

The Galvanic Anode Committee was formed in order to investigate the different types of metals which are suitable for galvanic anodes to supply current for cathodic protection of metal structures in soils or in solutions. Tests are being made to determine what effect the impurities in the metals may have on the solution potential, resistance of the corrosion products and current efficiency. A variety of chemical backfills are being investigated in order to determine the most suitable types of backfills and methods of installing backfills for various localities and soil and moisture conditions.

The First Interim Report covers test data presented on two large installations of galvanic anodes in the vicinity of Houston, Texas, a small installation of aluminum anodes near Edna, Texas, and a small installation of magnesium anodes in manholes to protect electric lead cable sheaths in Miami, Florida.

The test anodes were usually installed on operating structures to obtain the benefit of the current for protecting the structure while securing performance data on the anodes. Some of the committee members felt that installing the anodes on a non-polarizable structure would have certain advantages since with a stable structure potential, the changes in current output would be determined by factors such as the resistance to earth and polarization characteristics of the anodes. By making measurements of the resistance to earth of the anodes, the changes occuring on the cathodic structure could be separated from those due to changes occurring in the anode.

Where the anodes are located in permanent moisture, the variations in resistance to earth arise through formation of high resistance films of high resistance corrosion products and temperature changes.

Test anodes were usually placed vertically in augered holes to a minimum depth of 6′ in permanent moisture and below frost line. However, it was sometimes advantageous to install them horizontally in a trench to take advantage of low resistivity strata.

Anode spacings of 10 feet or more were used to avoid contamination of one backfill with another. Four anodes for each type backfill were installed to permit the excavation of one to three anodes for inspection and weight loss over a period of years without terminating the test.

A number of backfills of various chemical compositions were included in the committee investigations. These backfills were prepared by a number of different methods including: dry powder, well tamped around anode; prepared slurry; and premixed dry backfill puddled in hole with water. In addition to the composition of the backfills, the method of preparation has been found to affect the overall performance. Under some conditions, for example, clay mixtures in the form of a slurry result in voids between the anode and backfill resulting from a shrinkage of the backfill away from the anode. Voids may occur between the backfill and soils that shrink in dry weather. Where shrinkage occurs, the current output tends to be erratic, dropping to low values in dry weather and recovering in wet weather. In addition to the voids produced by backfill shrinkage, there is an effect resulting from a formation of hydrogen gas around the anode which increases its resistance to earth.

A number of types of gypsum are under test with zinc and magnesium anodes including molding plaster, unfibered wall plaster, anhydrous gypsum, and hydrated gypsum. These types are under test in the pure form and mixed with bentonite, natural clay, and other materials. Gypsum was used in many backfills for zinc and magnesium because of improved anode performance, general availability, low cost, and low solubility.

Two grades of zinc are included in the zinc anode test. These have a purity of 99.9% and 99.99%.

Initial zinc installations were made on operating lines in Houston to obtain performance data over a period of years. It was not feasible to take measurements more frequently than about 2 or 3 times a year; however, as the anodes were below normal ground water level, the performance was sufficiently stable so that frequent observations were not essential.

Typical performance curves of zinc anodes covering 5 years' operation are presented in the report. These data include the current output in milliamperes, resistance to earth of the anodes, solution potential of the anodes and the pipe-to-soil potential of the structure to which the anodes are connected. The results in general show that zinc anodes backfilled with a mixture of gypsum and clay have a relatively constant resistance to earth.

Available data indicate that zinc anodes operating in a gypsum backfill have current efficiencies, calcu-

lated
actua
Th
tests
pure
ganes
mate
and
regul
centa
Ce
than
the a
to sa
Ma
20 in
used
Th
magn
are d
back
back
sista
less
Da
anod
able
such
dens
sive
fact
Th
vari
falli
Co
y r
minu
curre
supp
od w
fact
curr

lated by dividing the theoretical weight loss by the actual weight loss, in the order of 90%.

The three grades of magnesium included in the tests are: cell magnesium, which is commercially pure grade, the major impurities being iron and manganese; an alloy magnesium containing approximately 6% aluminum, 3% zinc, and 0.2% manganese; and secondary magnesium which is similar to the regular alloy magnesium, but containing higher percentages of copper.

Cell magnesium has a higher solution potential than that of the alloy but available data indicate that the alloy has a higher current efficiency particularly to salt water environments and in acid soils.

Magnesium anodes about 4 inches in diameter and 20 inches long, weighing around 16 lb. were generally used for test installations.

Thirteen curves are plotted on the performance of magnesium anodes in the Houston tests. These data are on several different compositions of magnesium backfilled by various methods. The dry and puddled backfills show higher current outputs and lower resistance than the motor mixed muds, resulting from less tendency to form gas voids.

Data on the current efficiency on the magnesium anodes are tabulated. It was observed that considerable range in efficiency was obtained dependent upon such factors as type backfill, type anode and current density. These data are not sufficiently comprehensive to indicate the relative importance of various factors determining current efficiency.

The pH of the corrosion products removed from various anodes ranged from 8 to 12, the majority falling in the region of 10.

Corrosion products on zinc anodes were removed by making the anodes cathodic for a period of five minutes in a solution of sodium carbonate using a current density of 50-100 amperes per square foot supplied by a welding generator. The cathodic method was tried with magnesium but did not prove satisfactory. Some softening of the corrosion products occurred but the material was not removed from pits.

Immersing the magnesium anodes in a solution of chromic acid was effective in dissolving the corrosion product. This method was found to be expensive as the chromic acid bath was quickly depleted. Heating the anodes to a temperature of about 500° C. to soften the corrosion products and wire brushing was found satisfactory.

Tabulated data show the results of measurements on cell and alloy magnesium anodes installed in cable manholes in Miami, Florida. Relatively high current outputs were obtained in the manholes containing brackish water.

Tabulated data is also presented from the results of tests on packaged aluminum anodes installed at Edna, Texas.

The Interim Report includes the performance records of 132 galvanic anodes at Pierce Junction, Texas. Three metals are being tested in separate groups with 28 cell magnesium anodes and 40 alloy magnesium anodes in one group, 36 zinc anodes in a second group, and 28 aluminum anodes in a third group. Curves are presented showing the structure to soil potential and the current output of each anode acting in the group of anodes, the structure-to-soil potential and the current output of each anode acting as an individual anode, the open circuit voltage or effective driving voltage between the anode and the steel structure while operating in the group and while operating individually, and the curve of potential of the anode with respect to a remote copper sulfate electrode.

Comparison is made between a typical anode of one of each group of four in a typical backfill medium, comparing the current output in each particular backfill medium with respect to other backfill media and, in the case of the magnesium anodes, comparing the current output of high purity or cell magnesium anodes with alloy magnesium anodes in the same backfills.

Conclusions are drawn giving the general informative data deduced from a study of the operating curves.

First Interim Report

Recommended Practices for Surface Preparation of Steel
TP-6G—*Surface Preparation for Organic Coatings*

I. Surface Preparation for Steel

A. Surface Oxidation by Weathering

1) This age-old system employs the weathering, or atmospheric, chemical reaction on steel which forms a heavy layer of ferric oxide, thus neutralizing or destroying mill scale by the weather corrosion process. It is a general practice to remove the corrosion products with scrapers and wire brushes before applying either the inhibitor or primer.

2) When chisels or similar cleaning tools are used, care must be exercised that the tools are kept sharp. Dull tools will drive the corrosion product into the surface of the metal, thus creating a nucleus for corrosion products after the protective coating has been applied. These products are usually so firmly imbedded in the metal that it is impossible to remove them with a wire brush.

3) Unless primers with high compatability for oil and soil are used, the surface must be solvent cleaned before it can be primed.

4) In the average industrial atmosphere, a steel surface will completely weather descale in approximately 90 days. .

5) If metal weathers in a low humidity atmosphere, the metal loss will be slightly higher than with a surface prepared by blasting. In at atmosphere of high humidity, the losses in 90 days can reach approximately three times that of the metal removed by blasting.

B. Wire Brushing

1) Wire brushing will remove all loose scale and other corrosion products, but will not remove tight mill scale or tight oxide.

2) Wire brushed and scale covered steel does not constitute an acceptable surface anchor for all protective coatings. A protective coating with good adhesion and wetting characteristics must be used for good end results. Excessive power wire brushing often results in an undesirable burnished (polished) condition of the metal surface. A wire brush surface must be solvent cleaned before the average coating is applied.

3) When impact cleaning tools are used, care must be exercised that the tools are kept sharp. Dull tools will drive the scale and corrosion products into the surface of the metal, thus creating a nucleus for corrosion after the protective coating film has been applied. These products are usually so firmly imbedded in the metal that it is impossible to remove them with a wire brush.

C. Flame Conditioning

1) This method employs an intensely hot brush-like flame, that is rapidly passed over the metal to be descaled. The thermal gradient through metal and mill scale and the difference in expansion coefficient act to cause the loose, and some of the tight mill scale, to spall. Corrosion products are similary affected. On some work this process has been found desirable, since it also has the advantage that the local heat reduces the moisture film on the metal surface.

2) Immediately after flame conditioning, for good coating performance, it is necessary to wire brush the surface before applying any protective coating. Wire brushing will remove partially loose or upturned scale. A clean and soil-free brush must be used for this work. One can take advantage of this method by applying a coat of primer or protective coating to the metal surface before any new moisture can form on the surface.

3) Steel plates and shapes that can be flame cleaned, range in thickness from 3/16" and heavier. Extreme care must be exercised on sections lighter than 3/16" to prevent any possible warpage from local overheating. Operational cost is approximately 50 percent of that of white surface sandblasting. Average structural shapes can be cleaned at the rate of 3 to 5 tons per hour. If there are grease and oil deposits noticeable on the surface, solvent cleaning should precede the flame conditioning operation. The flame conditioning system is not recommended for the removal of old protective coating. Old protective coatings and grease carbonize under the flame and leave a residue on the metal which interferes with good adhesion of subsequent protective coatings. In some instances the operator may be subjected to toxic products due to the decomposition of the protective coating film and in such cases proper safety precautions must be observed.

D. Blast Cleaning

Open Dry System

1) This system employs near uniform grain size sand particles which are discharged through a nozzle outlet of specific size at a predetermined pressure, thus creating a sand velocity which produces sufficient impact and abrasion to remove mill scale, corrosion and other undesirable products from steel before protective coatings are applied.

2) The dry blasting method is accompanied by an

undesirable waste product, dust, against which the operator must be guarded through the use of protective clothing. Clean air for breathing must be supplied to the operator through a special helmet, to prevent silicosis attacks on his breathing organisms.

3) In order to reduce the health hazard caused by a high percentage breakdown of the blast sand, the selection of a very clean and hard sand becomes extremely important. The scale, rust, and other products removed from steel will produce an uncontrollable quantity of dust and waste. If it is at all possible, good blast sand should be reclaimed and reused until a maximum surface breakdown makes its further reclaiming uneconomical.

4) In order to establish surface condition tolerances for a specific end condition, three surface condition classifications for dry blasting are outlined as follows:

Condition No. 1 is the White Steel Surface Finish
which covers the complete removal of all corrosion products, all mill scale, and the grey mill scale binder, thus exposing the white metal for a good connection for either the adhesive or the bonding type coating. Single nozzle sandblasting will produce from 75 to 140 sq. ft. per nozzle hour (5/16" nozzle at 100 lb. pressure. It is suggested that nozzle distance from steel surface be 12" to 18").

Condition No. 2 is the Commercial Surface Finish
which includes the complete removal of all corrosion products, as well as all tight and loose mill scale. It does not include the removal of the grey binder. A commercial blasting job will look rather streaky; however, it does produce a very excellent surface anchor for either the adhesive or the bonding type coatings. Preparation speed with sand, 240 to 450 sq. ft. per nozzle hour (5/16" nozzle at 100 lb. pressure. It is suggested that nozzle distance from steel be 18" to 24").

Condition No. 3 is the Sand Brush-Off Surface Finish
which includes the complete removal of all corrosion products as well as all of the loose mill scale. *It does not include the removal of the tight mill scale.* However, the sand does produce on the tight mill scale an anchor pattern, which is found fully suitable for either an adhesive or bonding type coating. Preparation speed with 30 to 50 grit sand equals 650 to 1,000 sq. ft. per nozzle hour (5/16" nozzle at 100 lb. pressure. It is suggested that nozzle distance from steel surface be 20" to 30"). Before applying coating, surface should be solvent cleaned.

The advantages of these three specific conditions can be seen when one compares surface preparation costs with surface and service conditions. For instance, a product that must perform a lifetime of service without subjecting it to impact or high vibration stresses, will hold a coating as effectively on a surface that was prepared with the brush-off method, than the one that received a white steel preparation. However, if impact and other surface forces will produce undue stresses between metal and coating, nothing less than a commercial surface preparation should be selected. In some cases, the white steel surface will be necessary.

Note: The aforesaid surface conditions can be held within understandable tolerances. They do prove economical and practical. The average sand discharge runs 20 lb. per minute with a new 5/16" nozzle, operating under 100 lb. pressure using a 30 to 50 grit sand.

Closed Recirculating System

1) In addition to the conventional open systems, there is also available a closed portable system, which employs the continuous recirculating system.

2) The continuous system uses synthetic abrasives or steel grit and shot. While sand can be used with this system, its breakdown rate will require a too frequent recharging.

3) The abrasive is delivered to the blast nozzle in the same manner as outlined in Paragraph 1 on the open dry system of sandblasting. However, the nozzle is enclosed, permitting recovery of the grit immediately upon impingement upon the surface. A brush is mounted to the enclosure and acts as the surface sealer. The abrasive is returned to the blast tank through a large hose, is cleaned, and recirculated until it disintegrates. Separate suction is required for the recirculation process.

4) For angles, frames, pipes, and other shapes, brush shapes and cup enclosures must conform to the shape of the work. The adoption of this type of equipment should be carefully studied as its limitations permit use only under certain conditions.

5) The worker who operates the continuous recirculating system does not usually wear air helmets and other protective gear as used with open blasting equipment.

Wet System

1) In order to reduce dust to a minimum, the wet blast system employs a mixing chamber at the blast tank or near the blast nozzle, where water, or a mixture of water and an inhibitor, are added to the sand before it leaves the nozzle.

2) In this manner, the moisture subdues most of the dust, and in some cases, the operating conditions are more favorable and healthful.

3) Care must be exercised in selecting the wet system, since a sludge deposit generally remains on the surface after the blast job has been completed with this system. If the deposit is excessive, either a water rinse, air blast, blow-off, or light brushing with horsehair brush, should be employed in order to properly remove the undesirable products from the surface. An inhibited surface should not be cleaned with a wire brush, since bristle scratches will destroy the non-magnetic protective film.

4) Average production with wet system was found about the same as with a dry system.

5) A suggested solution to use in a wet system to inhibit corrosion is as follows:

a) **Concentrated Solution:**

Water	75 gal.
Trisodium Phosphate	300 lb.
Potassium Dichromate	75 lb.

This yields a concentrated solution of 100 gallons

b) **Diluted Solution for Actual Blasting:**

Concentrate (as above)	1 gal.
Water	20 gal.

In abnormally damp climates a more concentrated solution must be used.

A clean water rinse must follow this treatment. The prime coat must be applied immediately after the surface has dried.

E. Steel Grit and Shot Blasting

1) This system employs, as the name implies, grit or shot of specific grain size, which is discharged at a predetermined velocity which produces sufficient impact and abrasion to remove mill scale, corrosion, and other undesirable products from steel before protective coatings are applied.

2) The two general methods of propelling abrasive are: a) air blast which requires compressed air to propel the abrasive, and b) centrifugal or wheel blast, in which the abrasive is propelled by means of a paddle wheel. The air blast principle dates back many years while the wheel blast was developed during the nineteen thirties. The latter is a faster and less costly process.

3) Various types of abrasive are available for use with either type of application. Metallic abrasives available are: a) chilled iron-shot and grit, b) malleable iron-shot and grit, c) copper shot, d) high carbon steel shot, and e) synthetic non-metallic abrasives containing no free silica, therefore presenting no silicosis hazard; and various other organic abrasives of vegetable derivation used for specialized applications. Sand, aluminum oxides, etc., may also be used in air blast equipment but are not recommended in centrifugal blast equipment due to excessive wear on mechanical parts. Most of these abrasives are available in various sizes.

4) In general, copper and high carbon steel shot give the lowest operating costs due to long abrasive life and slight wear on machine parts. With the exception of sand, all of the abrasives listed above must be recovered for reuse to make the operation economical.

5) The cleaning rate of air blast on steel sheets and plates using a ⅜" diameter nozzle and 90 lb. air pressure will average from 3 to 6 sq. ft. per minute depending on the degree of cleanliness required, abrasive particle size, and type and thickness of scale on the steel. This nozzle would deliver approximately 72 lb. of abrasive per minute (metallic) and require about 36 horsepower. An average cleaning figure would be about .125 sq. ft. per minute per horsepower.

6) In comparison, a 2½" x 19½" diameter wheel for centrifugal blasting requires 20 horsepower on the drive, and will clean from 20 to 40 sq. ft. per minute depending on the same variables outlined above. The wheel would deliver an average of 400 lbs. of abrasive per minute at velocities up to 14,000 ft. per minute. To compare with air blast, this would be an average of 1.5 sq. ft. per minute per horsepower or more than ten times the area per horsepower.

7) Centrifugal wheels are made which deliver up to 1,000 lbs. of abrasive per wheel per minute and cleaning lines may consist of an unlimited number of wheels. Abrasive grit and shot can be recirculated from 100 to over 1,000 times, depending on the operation.

8) The surface roughness is dependent upon the shape, hardness, velocity, of the abrasive medium, exposure time, and the physical properties of the metal being blasted.

9) As a general rule, subject steel materials are used on indoor humidity-controlled blasting operations. High moisture content in the air stream causes early rusting of the steel blast particles, which often causes "balling up" or rusting together of considerable volume of the material, thus causing equipment choking or operational troubles.

General Notes on Blasting

1) For optimum mechanical bonding of coatings, the depth of surface etching produced by blasting is to be limited to one-third of the total thickness of the entire coating system. If a total coasting thickness of 6 mils is specified, the depth of etch should not exceed 2 mils.

2) Sand that is to be reused, must be dry and screened to original sizing in order to reproduce a near uniform anchor pattern.

3) There are synthetic cleaning materials available which are claimed to be superior to sand. Breakdown per blast operation is claimed to be lower and the inherent silicosis hazard of sand is reduced or completely eliminated. At times it is possible to purchase abrasive by-products from grinding wheel manufacturers, referred to as "seconds." They are available at a rather low price. These materials are fast cutting blast abrasives.

4) The surface produced by blasting is ideal for industrial work, theoretically. Yet there are factors which prevent its use in many cases. Possibilities of fire or explosion from sparking eliminate its use in hazardous areas; flying sand and dust particles make it inadvisable in some areas having a concentration of machinery due to possible damage to moving parts and bearing surfaces; danger of damage to the eyes, as well as the respiratory system, limit its use in areas with many personnel who are not involved with the sandblasting operation, and consequently, are inadequately protected.

5) If a sand is used, the particles should be nearly uniform in size and the sand should be free of clay. In some cases where clay is present, microscopic examinations have shown clay packed into the bottoms of the pits created in blasting and are the source of possible failure.

F. Chemical Pickling

1) Pickling in an acid bath removes scale and rust from the steel chemically. Grease, oil and drawing compounds should be removed from the surface prior to the pickling operation. It is common practice to immerse the steel product in a solution of sulphuric, hydrochloric, or phosphoric acid for sufficient time to remove the rust and scale. After pickling the work is thoroughly water rinsed to remove the acid from the surface.

2) In some cases, the water rinse is followed by a chromate or phosphoric-chromic rinse to retard corrosion development prior to further finishing. Alkali rinses are also sometimes used to retard surface oxidation after pickling but this alkali must be removed before application of an organic finish.

3) Nitric and hydrofluoric acids may also be used (commonly used on stainless and monel steel), de-

pending on the nature of the oxide that must be removed and the analysis of the steel to be pickled.

4) The use of inhibitors in hydrochloric, sulphuric and phosphoric acid pickling is advantageous in reducing the attack on the base metal while removing the scale and rust.

5) Pickling of steel should reach an end point when all corrosion products as well as loose and tight mill scale have been chemically dissolved or removed from the metal. The metal will appear grey-white and there will be a fine anchor pattern for good coating bond or adherence over the entire surface.

6) Redeposited salts on the surface, hydrogen embrittlement, smut deposits and the end use for which the product is to be used, should be given due consideration before selection of this chemical cleaning process is made.

7) Fumes from sulphuric, hydrofluoric, nitric and hydrochloric acid pickling baths are corrosive and should be properly hooded.

8) Steel surfaces properly chemically pickled and rinsed will provide a satisfactory substrate for finishing. These surfaces when finished will provide better service life than the original surface by removing the deleterious deposits that cause premature failure.

G. Electrolytic Pickling

1) Process consists of anodic work and cathodic assembly, or the reverse thereof, submerged in a suitable electrolyte. Current is adjusted to a density, as found specifically required for the job.

2) Electrolytic pickling in molten salts or molten caustic is also used for removing scale and corrosion products from the metal. These methods produce clean and uniform surfaces, and are free of disadvantages of acid pickling. Metals must be cleaned in a water rinse prior to painting.

H. Roller Roughing at the Mill

1) The scale-free sheets are passed through a set of rolls that have been slightly roughened by mechanical or chemical means. The sheets that pass through these rolls receive a rough or matte finish, constituting a surface anchor for the coating. For example, ASTM D-609-46T outlines the surface condition commonly known as Carnegie-Illinois No. 5 finish, as a velvet or satin finish.

General Notes on Surface Conditioning

The end condition of steel surfaces is set up under four specific classifications:

1) **Surface cleaning** with solvents, alkalies, and emulsions for the purpose of removing all soil, grease, and oil, etc. This treatment does not react with the metal and must be painted immediately or followed by either the **surface reaction** or **surface conversion** treatment.

2) **Surface reaction** with dilute acids produces a slight etch on the metal. Since the reaction is only slight, paint should be applied within one hour after metal so treated has dried.

3) **Surface conversion** with chemical solutions change the iron and steel surface to a nonmetallic coating which can be measured.

4) Vinyl metal conditioners are sprayed on to inhibit the metal, give temporary protection against corrosion, enhance adhesion of subsequent coatings to metal, and prevent corrosion creepage in case of damage.

I. Surface Cleaning

With Solvents

1) Organic solvents are used in various ways to remove soil from metal surfaces. In small shops, or on large structural projects, where mechanical cleaning equipment is not available or cannot be economically employed, the practice is to wipe the surface of the metal with rags wetted with solvents. This cleaning method leaves much to be desired. The rags quickly become contaminated with oil and grease and a light film of oil and grease is usually left on the metal surface. Rags must be kept clean during hand wiping. Salts, alkalies, acids, chalk marks, drawing compounds, and other foreign elements are insoluble in organic solvents and cannot be removed by such expedients. When this method of cleaning is necessary, a primer with a high tolerance for oil should be used as the base coat for the finish.

2) The most satisfactory method of solvent cleaning is the vapor degreasing process. In this process the metal is passed through hot solvent vapors that condense on the cooler metal and wash the surface. The principle of the vapor degreaser is quite elemental. Equipment for the process consists of a solvent tank or boiler provided with a thermostatically controlled source of heat. Above the boiler is a vapor chamber. The top walls of the vapor chamber are cooled to a predetermined height to provide a condensing area that does not permit the hot vapors to escape from the top of the chamber. When the system is in operation the solvent is held at boiling temperature and the metal to be cleaned is constantly washed by clean solvent condensing from the vapor phase. In many vapor degreaser systems it is common practice either to immerse the work in the solvent or to spray solvent on the work before passing through the vapor chamber. This step will remove the major part of the oil and grease and greatly reduce the time necessary in the vapor chamber. When properly done, vapor degreasing will completely eliminate oil and grease from metal surfaces, also from seams and intricately formed parts of fabricated articles. Fire hazards, usually present in other cleaning processes, are not a threat because the chlorinated-organic solvents used in degreasers do not ignite at ordinary temperatures.

3) Vapor degreasing has its disadvantages, in that it will not remove mill and shop soil without spraying or wiping. Also, vapor degreasing will not remove soap or water soluble salts. A water rinse after the vapor degreasing operation is beneficial in removing these materials.

4) Most vapor degreasing solvents create a health hazard that should be considered in the installation of this type of cleaning.

5) Solvent cleaning is probably the best method for removing waxes from metal surfaces.

6) Primers must be applied to solvent cleaned surfaces as quickly as possible to prevent the formation of rust.

With Alkaline Compounds

1) Cleaning of a metal surface by water solutions of alkalies is another widely used method. The alkaline compounds usually are a mixture of two or more compounds, some of which are soluble alkaline silicates, phosphates, carbonates, and hydroxides. Rosin, soaps, and other emulsifying agents are sometimes added to the alkaline mixtures.

2) Another addition to alkaline cleaners are the so-called wetting agents or surface active agents. Sodium salts of sulfonated alcohols are a common variety of wetting agents. These compounds lower the surface tension between the metal surface and the solution and accelerate the cleaning process because of the better wetting qualities of the solution.

3) Alkaline formulas spread over a wide range and these cleaners are available for almost every type of metal cleaning, from heavy greases to light oils. They will remove shop dirt, soil, hand marks, acid, and just about everything else except insoluble compounds such as chalk marks and corrosion products.

4) Two methods are employed in alkaline cleaning—"soak" or immersion cleaning, and mechanical washing with sprays. The immersion process consists of dipping the metal parts in a still tank provided with a source of heat. Heat is an important factor in alkaline cleaning and an adequate supply must be available when speed and thorough cleaning are necessary. A solution that will do a thorough cleaning job at 212° F. in two minutes may require 7 or 8 minutes at 200° F., or 12 to 15 minutes at 165° F.

5) Solutions used for immersion cleaning carry much higher percentages of cleaner than those used in mechanical or spray units. For example, 2 to 6 ounces of cleaner are used in a soak tank, while ¼ to 1 ounce is enough for the mechanical washer. The difference in the cleaner content of these two solutions indicates the great advantage of the washing action of the solution when applied to the metal surface by sprays under pressure. Because of the greater efficiency of the mechanical unit it is widely used in volume production.

6) Metal cleaned in alkaline cleaning solutions must afterwards be thoroughly rinsed in clean water. A rinsing procedure that fails to remove all residual alkali will give unsatisfactory results since most organic finishes are readily attacked by alkalies. Traces of alkali on the metal surface in most cases are even more detrimental to organic finishes than traces of oil or grease.

The more satisfactory alkaline cleaning systems include an acid or neutralizing rinse following the water rinse. Dichromates or dilute chromic acid may be used for this purpose and are permitted to dry on the metal surface. These materials neutralize traces of alkala and appear to partly passivate the metal surface. When properly used, these rinses will prolong the life of the finish considerably. To reduce shop dirt and other contaminations to a minimum, prime coat should be applied as quickly as is possible.

With Emulsions

1) Emulsion cleaning is also employed to some extent in the metal industry. Organic solvents such as kerosene are emulsified with pine oil, soaps, or other emulsifying agents, and applied to the metal by immersion or spray. Additions of small amounts of alkali compounds to these emulsions are sometimes recommended where heavy greases are to be removed.

2) Emulsion cleaners are especially advantageous as mediums for removing the soil from steel ahead of chemical treatments that convert the surface, i.e., phosphate coatings. They may help to retard rusting between stages of spray units and are beneficial in controlling the coating to be obtained.

3) Where storage of cleaned metal between operations is a factor, emulsion cleaners are beneficial in retarding corrosion.

J. Surface Reaction

By Acid Cleaning

1) Alcoholic phosphoric acid cleaners consist of phosphoric acid and an organic grease solvent and when reduced with water produce a solution for cleaning steel.

2) They may be used to remove grease, oil, rust and light annealing oxide. Heavy drawing compounds should be removed from metal by a surface cleaning method prior to the use of acid cleaners.

3) There are two types, wash off and wipe off, and they are generally applied at room temperature by brush, swab, or steel wool.

4) Articles cleaned with the wash off type should be washed after treatment with clean water, preferably hot, to facilitate drying. The wipe off type is wiped up with clean rags after application. Acid residue should be completely removed for best finish results.

5) Metal cleaned with acid cleaners should be thoroughly dried before painting.

6) Metal surfaces properly cleaned with acid cleaners provide a satisfactory base for finishes as a result of the etch obtained. Finished metal surfaces cleaned in this manner are improved over metal surfaces cleaned by cleaning methods noted previously which do not etch the metal. To reduce shop dirt and other contaminations to a minimum, prime coat should be applied as quickly as is possible.

Chemical Cleaning and Pretreatment System

1) Salts of phosphoric acid with detergents are designed to simultaneously clean and condition rust free iron and steel surfaces in preparation for paint.

2) The solution is operated at temperatures of 150-170° F., and is sprayed in a specially designed washing machine. It has particular merit where three or four-stage power washers are available.

3) The process for application is generally as follows:

     a) Stage 1—Spray chemical cleaner
         Stage 2—Spray water rinse

Stage 3—Spray acidified rinse
<center>or</center>
b) Stage 1—Spray chemical cleaner
Stage 2—Spray chemical cleaner
Stage 3—Spray water rinse
Stage 4—Spray acidified rinse

4) The treatment produces a surface over which organic finishes will have better durability and adhesion than they do over alkali, acid, or solvent cleaned surfaces, and will also inhibit rusting of iron and steel parts between operations.

5) To reduce shop dirt and other contaminations to a minimum, prime coat should be applied as quickly as is possible.

K. Surface Conversion

1) These chemical solutions convert the iron and steel surfaces to non-metallic coating adapted to inhibiting corrosion and increasing the adhesion and resultant durability of applied organic finishes.

2) The decrease in durable life of the organic finish is due to:
a) Insuring a chemically clean, grease-free surface for paint.
b) Providing a corrosion inhibiting surface on which to paint.
c) Providing a non-conducting bond between base metal and the paint.

3) The process for the application of the coating treatments is generally as follows:
a) Cleaning
b) Hot water rinsing
c) Chemical treatment
d) Water rinsing
e) Acidified rinsing

4) Most of the surface cleaning methods outlined previously are applicable for cleaning the metal prior to the chemical treatment.

5) The chemical treatment is accomplished by either immersion application or by power spray washing type equipment.

6) In general, the chemical treatment solution is heated. The temperatures vary according to the type of solution from 70° F. to 210° F.

7) Chemical coating solutions are generally a balanced phosphate solution containing an accelerating agent to produce a uniform crystalline phosphate coating.

8) Coating weight determinations may be used to establish the efficiency of the solution.

9) These coatings when finished provided the most resistant system of metal preparation in commercial use today.

L. Vinyl Metal Conditioner (Wash Primer)

1) The vinyl metal conditioner is designed to:
a) Replace the inhibitive metal prepainting inhibiting washes,
b) Give temporary protection against corrosion,
c) Prevent creepage of corrosion under the paint film where damage has occurred, and
d) Provide a desirable adhesive base for subsequent paint films.

2) The product contains inhibitor, pigment, and binder. It should not be considered as a replacement for the anti-corrosive primer, but as a supplement to the anti-corrosive and other paints. The conditioner is considered part of a surface preparation and not of the paint system.

3) Vinyl conditioners differ from conventional paints in that they become insoluble after being applied to the metal. This insolubleness takes place over a wide range of temperature and humidity and is not appreciably affected by either. The conditioners will give temporary protection against corrosion, but their use as shop coats is governed by the length of time that they are exposed to the weather, before the prime coat is applied.

4) Vinyl conditioners should be applied to the metal as soon as possible after the metal has been prepared.

5) Aqueous phosphoric or other pretreatment should not be used before applying the conditioner. Best results have been obtained, when the conditioner comes directly in contact with the clean metal. Mechanical or chemical roughening of the steel surface is not a prerequisite to its use, but relatively clean metal attributes to its success.

6) There are several different types of conditioners or wash primers available. All are good for ferrous metals. One of the most common standard formulations is known as Bureau of Ships Paint Formula No. 117.

II. Surface Preparation of Galvanized Surfaces

1) Galvanized steel is steel which has been coated with metallic zinc.

2) It has been found that galvanized steel provides a poor foundation for paint unless given a pretreatment either at the mill or in the field. Satisfactory results have been obtained from the following treatments.
a) Weathering for at least three months.
b) Treatment with phosphoric acid base materials (proprietary materials are available).
b-1) Salts of phosphoric acid with phosphoric acid and accelerating agents.
b-2) Phosphoric acid with grease solvents.
c) On properly cleaned galvanized steel, the use of Bureau of Ships Paint Formula No. 117 (a wash primer) is a good foundation for subsequent coatings.

3) Soil or contamination should be removed before painting.

III. Maintenance and Repair Jobs.

1) On maintenance and repair jobs, the surface preparations can be handled as per any of the aforesaid new steel product systems, with the following exceptions.
a) For the removal of old coatings, good paint removers are usually more economical to use than either a blast, brush, or flame cleaning system.
b) When patch work is blasted or otherwise cleaned, the operator should see to it that the old or remaining plaint is feather-edged

sufficiently, to permit the new coating to form a near uniform surface assembly.

c) When inhibitor is used on old work, care should be exercised that the inhibitor does not spread onto paint surfaces that must be joined with patch work during repair operations, or creep into crevices from which it is difficult to wash off.

d) Care must be exercised when old coatings are removed with flame cleaning apparatus. In some instances, the operator may be subjected to the toxic products due to the decomposition of the protective coating film, and in such instances, proper safety precautions must be observed. Old protective coatings and grease carbonize under the flame and leave a residue which interferes with good adhesion of subsequent protective coatings. It is therefore important that maintenance men remain aware of this disadvantage.

IV. Assembly of Dissimilar Metals

1) Assembly of dissimilar metals should be avoided whenever possible. If it is necessary to contact dissimilar metals, the problem of galvanic corrosion is usually present. To prevent this, an insulator must be provided between the two metals. This can be done with barrier type coatings with high resistance and with anodic coatings. The trend has been to use products such as corrosion inhibitor impregnated tape, rubber, plastics, or fiber insulating barriers.

General Notes on Surface Preparation of Steel

A. For good coating performance, the anchor depth on any steel surface should not exceed one-third of the total thickness of the coating system. Anchor depth for a 6 mil coating system should not exceed 2 mils.

B. Sand residue and dust must be removed from any surface before a prime or first coat is applied.

C. Coatings which oxidize are to be applied to metal only when metal is dry and the atmospheric temperature around the metal is above 40° F. Application of a coating at a lower temperature should be discussed with the paint manufacturer. Coatings which depend on solvent evaporation for drying, have been succesfully applied at temperatures as low as +10° F.

D. Coating life can be prolonged if sharp edges and demarcations are beveled or rounded for good coating coverage and adhesion.

E. Weld flux and weld spatter should be removed completely before a coating is applied. Weld fluxes usually contain a large proportion of alkaline borades which tend to affect the paint film detrimentally.

F. Grinding a surface with an abrasive wheel can be considered a surface preparation method. It produces a good anchor for all types of coatings. However, the metal losses are generally very high and the process is costly. Economically, it should only be used where other processes must be ruled out.

G. There are also available a number of tools and equipment which employ the centrifugal hammer principle and the milling principle for purpose of removing rust, scale, and loose paint products. We restrict interpretation due to insufficient specific data on this equipment.

CORROSION CONTROL — NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Corrosion in a Large Invert Sugar Tank

By H. W. FOELSCH*

INVERT SUGAR is used extensively in the manufacture of bakery goods, candy and soft drinks. Normally it is transported and stored as a heavy, viscous syrup at from 72 percent to 78 percent sugar solids. The pH varies be- tween 4.0 and 4.5. As a result, pitting and rusting in unlined or improperly lined large steel storage vessels is a common occurrence.

Figures 1 and 2 depict interior sur- faces of a compartmented 23,000 gallon capacity invert sugar storage tank, 11½ feet in diameter and 31 feet long. From 1936 to 1946 all interior surfaces were coated once a year with a heavily pig- mented, short-oil, air-dry phenolic paint. In this period, the stored syrup upon analysis, showed no iron contamination within the ensuing six months after painting. After six months, iron content increased from .5 parts per million to a maximum of 6.5 parts per million, with a gradual color change from water white to pinkish tan. This maintenance proce- dure was generally unsatisfactory as painting the tank interior, each year, in- volved the expenditure of approximately 140 man hours and 15 gallons of paint.

Figures 3 and 4 depict the interior of the same tank three and one-half years after lining with .008-inch to .010-inch of heat-reactive phenolic resin. The lin- ing procedure included:

1. Sandblasting to even grey steel.

2. Application, by spray, of six coats of 40 percent phenolic resin solids solution.

3. Force dry with hot air between coats.

4. Final cure at 310° F steel tempera- ture for two hours.

This lining material was selected as the result of an accelerated test program involving elevated temperatures (200° F). At the expiration of a 120-day test the phenolic-coated test bars showed no attack or loss of weight. No taste or odor had been imparted to the invert sugar syrup in which the coated bars had been immersed.

In the three and one-half years since installation the lining itself indicates no deterioration or loss of gloss. Minimum anticipated life is ten years, with no more than minor repairs after that period. Total cost of the phenolic lining was less than one third the total cost of ten yearly paint applications. In addi- tion "down time" has been eliminated and the iron content of the contained syrup has at all times been well below the maximum permitted.
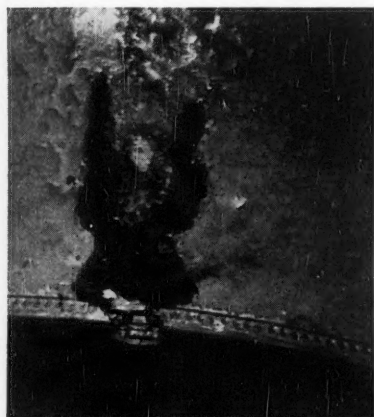
Figure 1
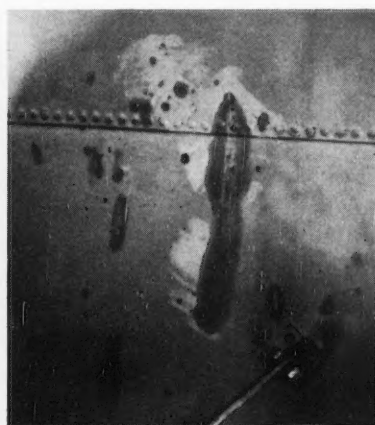
Figure 2
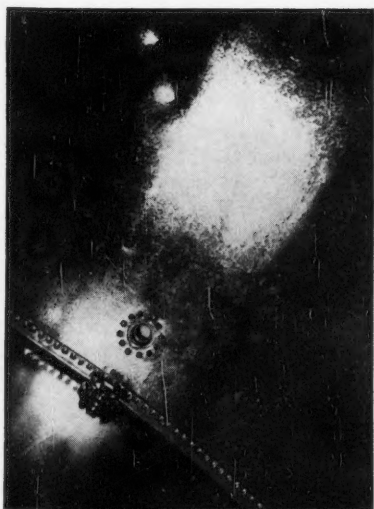
Figure 3
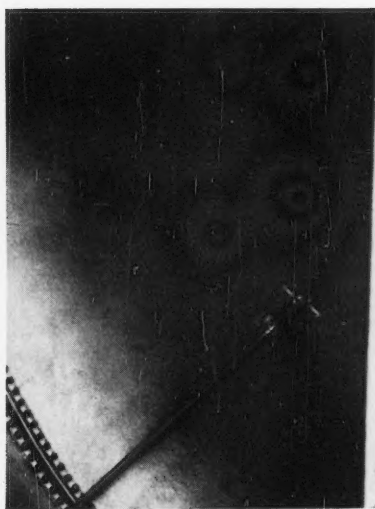
Figure 4

* Stalplc Coating Corporation, Chicago, Ill.
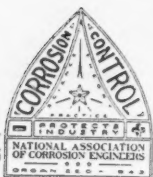
NACE News

Meetings Scheduled in North East Region

Scheduled meetings for the remainder of 1950 by North East Region NACE and sections in the region have been listed as follows by E. R. English, secretary-treasurer:

September 13—260 S. Broad, Philadelphia—North East Region Trustees, general business.

September 13—Poor Richard Club, Philadelphia, Philadelphia Section.

September 20—Building Trades Employers' Ass'n, New York City, Metropolitan New York Section.

October 19—Place undetermined, North East Region Trustees, general business.

October 27—Engineers' Club of Philadelphia, Joint meeting, Philadelphia Section and ASM (Tentative).

November 15—Place undetermined, joint region-section meeting sponsored by Western New York Section.

December 6—Place undetermined, North East Region Trustees, general business.

December 6—Building Trades Employers' Association, Metropolitan New York Section.

December 13—Poor Richard Club, Philadelphia, Philadelphia Section.

Money for Corrosion Books Given Library

Corpus Christi Section presented a $50 check to Mrs. Margaret Hardy, librarian of La Retama Library, for the purchase of books on the subject of corrosion for the library's technical section.

Thirty-seven members and guests were present for the May 24 dinner meeting at Princess Louise Hotel where John Nee, of Briner Paint Manufacturing Co., Corpus Christi, Texas, spoke on "Protective Coatings for Industry," and Messrs. Jack Breslin and Matt Harvey of Formica Company presented a film, "The Formica Story."

The June 28 meeting was scheduled at the same place with Charles Ward, Maintenance Foreman and Corrosion Engineer, Magnolia Petroleum Company, as the speaker on "An Experience in Pipe Line Maintenance." The Shell Pipe Line Corporation film "Pipe Lines" also was scheduled.

**Corrosion
News Deadline:
10th of Month
PRECEDING
Date of Issue**

Shreveport Section Plans Corrosion School to Be Held Three Days, September 13-15

NACE MEMBERS

IF You Change Addresses

IF You Change Company Affiliation

IF You Change Positions

Please notify the Central Office NACE, 919 Milam Building, Houston 2, Texas, so that you will get CORROSION without delay and that association records can be kept abreast of your progress.

THANKS!

Committees Are Named By Houston Section

Committees have been named by Houston Section as follows:

Program—Charles Gribble, Metal Goods Corp., chairman; L. G. Sharp, Gene Wallace, Mack Parr, George Holm and Ray Cherry.

Arrangements—Melvin A. Judah, NACE, chairman; Ed Thorney, Jr., Charles Davis, Jr., Gordon Doremus and John Watts.

Membership and Attendance—R. O. Brendel, Crane Company, chairman; E. P. Doremus, Lyle Sheppard, John Watts, MacGregor Parr, C. A. Blanchard, C. L. Mercer, W. Vierling and Karl Luger.

Entertainment—Charles Scammon, Houston Oil Field Material, chairman; Melvin A. Judah.

Pipe Line Corrosion Topic at Corpus Christi

"An experience in Pipe Line Maintenance" was the subject of a talk by Charles Ward, Refining Department, Product, Pipe Line and Terminal Division, Magnolia Petroleum Corp., at the dinner meeting June 28 of Corpus Christi Section. The meeting at Princess Louise Hotel was attended by 30 members and guests. A film "Pipelines" by Shell Pipe Line Company, also was shown.

No meetings are scheduled by the section during July and August, but a barbecue is being planned for members, wives and families September 15.

Shreveport Section plans to hold a 3-day corrosion school September 13-15 at the Caddo Hotel, Shreveport, it was announced by M. J. Olive secretary of the section. Pat Miller of Texas Eastern Transmission Company is chairman of the program committee. Aim of the school will be to familiarize field men with the nature of and means of controlling corrosion through discussions and demonstrations.

The regular June meeting of Shreveport Section at the Caddo Hotel consisted of a discussion of rectifiers and ground beds led by W. A. Broome, Arkansas Natural Gas Companies.

New officers of the section effective with the June meeting are H. V. Beezley, United Gas Corporation, chairman; J. A. Creevy, Youngstown Sheet and Tube Co., vice-chairman; M. J. Olive, Arkansas Natural Gas Companies, treasurer and Tom Holcombe of Holcombe and Stearns, secretary. All are of Shreveport.

No meetings by the section are scheduled for July and August.

Robert Pope Retiring From Bell Laboratories

Robert Pope, one of the early members (February 5, 1944) of the National Association of Corrosion Engineers, and on the first board of directors, retired August 1, 1950, as a member of the technical staff of Bell Telephone Laboratories, Murray Hill, N. J. Mr. Pope has been active in the affairs of the association and a frequent contributor of technical material to the association's publication CORROSION. His retirement marks his 26th year in corrosion work, especially in development and research in connection with underground lead sheathed telephone cables.

Mr. Pope is a graduate of Stevens Institute of Technology, Hoboken, N. J., and was first employed by the Long Lines Engineering Department of American Telephone and Telegraph Company. He was transferred to the Department of Development and Research of American Telephone and Telegraph Company in 1924. This department was merged with Bell Laboratories in 1934. His principal hobby is photography.

He is a member of Technical Practices Sub-Committees 2 and 4.

•

A list of addresses of new members and changes of addresses of old members is a monthly feature of CORROSION magazine.

Top—Me
at San Ja
Section's

Hous Dinn

A cr
Parker
Housto
San Ja
grounds
ments f
meeting
features
23 mee
88 mer
were s
supplie

Harr
nical pu
outline
Charles
tertainr

Next
held in
announ

CORRO
notices
than N
vestigat
who kr
in COR
Office
the inf

Case Institute Corrosion Course Program Given

Wayne Broyles Photo

Top—Members and guests of Houston Section NACE at dinner and business sessions in the Cave at San Jacinto Inn, San Jacinto Battleground near Houston in June. Bottom—Some of the Houston Section's member on deck of Parker Bros. yacht "Mary Gene" cruising down the Houston Ship Channel.

Nine two to two and one-half hour lecture periods, with adequate time for discussion have been scheduled tentatively at Cleveland, Ohio, for the Case Institute of Technology corrosion short course to be held September 25-29, under direction of Dr. R. B. Hoxeng. Dr. Hoxeng said the lecture course is designed as a refresher for those actively engaged in corrosion prevention, yet will not be too advanced for those just entering the field.

Authorities in the field of corrosion and corrosion prevention who have accepted are F. L. LaQue, The International Nickel Co., Inc., New York; Dr. R. B. Mears, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.; H. A. Robinson, Dow Chemical Company, Midland, Mich.; Prof. Mars G. Fontana, Ohio State University, Columbus, Ohio, and Professors W. von Fischer, E. G. Bobalek and R. B. Hoxeng of Case Institute. Of the lecturers Mr. LaQue and Dr. Mears and past presidents of the National Association of Corrosion Engineers; Dr. Fontana is chairman of the NACE technical practices committee and the others are noted for their contributions to corrosion science.

The Case Institute course is the second such undertaking in which NACE has cooperated, the first being at the University of Texas, Austin, in September, 1949.

Case lectures will be given two daily except Friday during the week of September 25.

TENTATIVE SCHEDULE
CORROSION SHORT COURSE
Case Institute of Technology
Cleveland, Ohio—Sept. 25-29, 1950

MONDAY, SEPTEMBER 25
  a. Fundamentals
  b. Fundamentals
TUESDAY, SEPTEMBER 26
  a. Pertinent Fundamentals of Metallurgy
  b. Types of Corrosion and Choice of Materials
WEDNESDAY, SEPTEMBER 27
  a. Use of Inhibitors and Chemical Treatment
  b. Electrolysis and Cathodic Protection
THURSDAY, SEPTEMBER 28
  a. Protective Coatings—Fundamentals
  b. Protective Coatings—Application
FRIDAY, SEPTEMBER 29
  a. Designing to Prevent Corrosion

Houston Section Holds Dinner and Cruise

A cruise on a yacht furnished by Parker Brothers Company down the Houston Ship Channel, dinner at the San Jacinto Inn at San Jacinto Battlegrounds and a discussion of arrangements for the 1950 South Central Region meeting scheduled October 9 and 10 were features of the Houston Section's June 23 meeting. The event was attended by 88 members and guests. Refreshments were served aboard the yacht by 17 suppliers.

Harry Waldrip, chairman of the technical program for the regional meeting, outlined plans and reported on progress. Charles Scamman was in charge of entertainment for the June 23 meeting.

Next meeting of the section will be held in September at a date to be announced.

•

Corrosion magazine seeks for publication notices of meetings of associations other than NACE which conduct corrosion investigations and research work. Members who know of such activities not reported in Corrosion are asked to notify Central Office so steps may be taken to publish the information.

Berry Will Address Session at Cleveland

N. E. Berry, Servel, Inc., Evansville, Ind., vice-president of NACE, will address members of the Cleveland Section at its meeting scheduled to be held during the Case Institute Corrosion Short Course September 25-29. Persons attending the short course will be invited to attend the meeting and hear the address.

R. B. HOXENG
CASE INSTITUTE OF TECHNOLOGY
UNIVERSITY CIRCLE,
CLEVELAND 6, OHIO

(Clip This Form and
(Mail for More
(Information

I am interested in the SHORT COURSE ON CORROSION. Please send OFFICIAL REGISTRATION APPLICATION to the address below:
(Print or typewrite plainly)

Name...

Street..

City..Zone......State..............

Technical Program for New York Conference Set

Eleven symposia and two round table discussions have been scheduled tentatively for the 1951 Conference of the National Association of Corrosion Engineers to be held March 13-16, 1951, at Hotel Statler, New York, N. Y. Prof. Norman Hackerman, of the University of Texas, Austin, chairman of the technical program committee, has projected arrangements for 47 papers. G. E. Seidel, Amercoat Corp., Chicago, and L. B. Donovan, Consolidated Edison Co., New York, respectively, exhibits and general chairman for the conference, stated there will be 106 booths available at the Statler for the annual exhibit.

The tentative technical program is:

Tuesday, March 13

2 to 3 p.m.—Corrosion Principles Symposium, one paper.
3:10 to 5 p.m.—Water Industry Symposium, 3 papers.
   Food Industry Symposium, 3 papers.

Wednesday, March 14

9 to 12 noon—Pipe Line Industry Symposium, 4 papers.
   Chemical Industry Symposium, 4 papers.
2:30 to 5 p.m.—Transportation Industry Symposium, 4 papers.
   Protective Coatings Symposium, 4 papers.

Thursday, March 15

9 to 12 noon—Oil and Gas Industry Symposium, 4 papers.
   Cathodic Protection Symposium, 4 papers.

2:30 to 5 p.m.—Electrical and Communications Industries Symposium, 4 papers.
   Symposium on Industrial Use of Corrosion Inhibitors, 4 papers.

Friday, March 16

9 to 12 noon—Round Table on General Corrosion Problems.
   Round Table on Pipe Line and Underground Corrosion.

Symposia Personnel

Chairmen and co-chairmen of Symposia who have accepted include:

Oil and Gas Industry Symposium: T. S. Zajac, Shell Oil Co., Houston, Texas, chairman; H. E. Waldrip, Gulf Oil Corp., Houston, Texas, co-chairman; E. Q. Camp, Humble Oil & Refining Co., Baytown, Texas, co-chairman.

Pipe Line Industry Symposium: S. S. Smith, Shell Oil Co., New York, chairman; W. E. Huddleston, Huddleston Engineering Co., Bartlesville, Okla., co-chairman; I. B. Tietze, Phillips Pipe Line Co., Bartlesville, Okla., co-chairman.

Protective Coatings Symposium: Kenneth Tator, Kenneth Tator Associates, Coraopolis, Pa., chairman; C. G. Munger, Amercoat Corp., South Gate, California, co-chairman; Raymond P. Devoluy, C. A. Woolsey Paint and Color Co., Inc., New York, co-chairman.

Transportation Industry Symposium: Merritt A. Williamson, Pullman-Standard Car Mfg. Co., Hammond, Ind., chairman; Otto E. Kirchner, American Airlines, New York, N. Y., co-chairman;

Joseph Winlock, The Budd Company, Philadelphia, Pa., co-chairman.

Electrical and Communications Industry Symposium: Kenneth C. Compton, Bell Telephone Laboratories, Murray Hill, N. J., chairman; Walter C. Honecker, Indiana Bell Telephone Co., Indianapolis, Ind., co-chairman; H. N. Trueblood, Dobbs Ferry, N. Y., co-chairman.

Industrial Use of Corrosion Inhibitors Symposium: Aaron Wachter, Shell Development Co., Emeryville, Calif., chairman; Morris Cohen, National Research Council, Ottawa, Canada, co-chairman; John W. Ryznar, National Aluminate Corp., Chicago, Ill., co-chairman.

Chemical Industries Symposium: W. Z. Friend, International Nickel Co., Inc., New York, chairman; Mars G. Fontana, Ohio State University, Columbus, Ohio, co-chairman; F. A. Rohrman, University of Colorado, Boulder, Colo., co-chairman.

Names of those responsible for other committees will be published

Assisting Dr. Hackerman as co-chairmen of the technical program are R. L. Bullock, Interstate Oil Pipe Line Co., Tulsa, Okla.; G. W. Seagren, Mellon Institute, Pittsburgh, Pa., and Aaron Wachter, Shell Development Co., Emeryville, Calif.

Cathodic Protection Symposium: Sidney E. Trouard, New Orleans Public Service, Inc., New Orleans, La., chairman; A. W. Peabody, Ebasco Services, Inc., Jackson, Miss., Y. W. Titterington, Dowell Inc., Tulsa, Okla., co-chairmen.

First ... rangeme... NACE ... held Ma... July 12... solidate... Place, N... general ... sided.

Among ... agenda ... were:

Recon... rooms a...

Have ... tion for... in a pac...

A fas... guests a...

A tri... quarters...

Comb... function...

Advan...

Daily ...

Ticke... bered.

Meeti... March ...

Fashi... wegian ...

Lapel... pointers...

Confe... vision.

Daily ... program...

Impro...

Follo... committ... of perso...

Gener... Donova... of N. Y... New Yo...

Techn... Hacker... partmen...

Local... Hamilto... pany, 2... Pa.

Exhib... Amerco... Chicago...

Regis... Commit... Edison ... Room 1...

Hotel ... tee, F. ... ing Con...

Enter... Stuart, ... cal & ... York, N...

Ladie... Rolph, ... St. & E...

Print... Anglo-... Johnson...

Publi... H. C. ... Philade...

Confe... tee, The... Co., Ind...

Hosp... W. A. ... mond, ...

Arrangements for '51 Conference Discussed; Chairmen of Local Committees Are Named

First general meeting of the local arrangements committee for the 1951 NACE Conference and Exhibition to be held March 13-16 in New York was held July 12 beginning at 10 a.m. at Consolidated Edison Company, 4 Irving Place, New York City. L. B. Donovan, general chairman of the conference, presided.

Among the items on an extensive agenda considered by the committee were:

Recommend multiple occupancy of rooms at hotel where possible.

Have programs and printed information for distribution at registration desk in a package.

A fashion show and tea for women guests attending the conference.

A trip to the United Nations headquarters.

Combination ticket for entertainment functions.

Advance registration.

Daily registration lists.

Tickets to all functions to be numbered.

Meeting room schedule for committees March 12.

Fashion show and tea aboard a Norwegian liner for lady guests.

Lapel microphones and electrical pointers.

Conference publicity on radio and television.

Daily mimeographed sheet conference program.

Improved badges.

Following are names of conference committees, with the name and address of person in charge:

General Conference Committee, L. B. Donovan, Consolidated Edison Company of N. Y., Inc., 4 Irving Place, Room 630, New York 3, N. Y.

Technical Program Committee, N. Hackerman, University of Texas, Department of Chemistry, Austin, Texas.

Local Arrangements Committee, H. L. Hamilton, Keystone Pipe Line Company, 260 S. Broad St., Philadelphia 15, Pa.

Exhibition Committee, G. E. Seidel, Amercoat Corp., 4554 North Broadway, Chicago 40, Ill.

Registration and Information Sub-Committee, F. Kuhlman, Consolidated Edison Co. of N. Y., Inc., 4 Irving Place, Room 1350-S, New York 3, N. Y.

Hotel and Meetings Rooms Committee, F. J. LeFebvre, Electro Rust-Proofing Corp., 1 Main St., Belleville, N. J.

Entertainment Sub-Committee, L. Stuart, The Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York, N. Y.

Ladies Sub-Committee, Mrs. Florence Rolph, Willard Hawes & Company, 48th St. & East River, New York City 17.

Printing Sub-Committee, G. Hull, Anglo-American Varnish Company, 55 Johnson St., Newark, N. J.

Publicity Sub-Committee, R. English, H. C. Price Company, P. O. Box 6120, Philadelphia 15, Pa.

Conference Coordination Sub-Committee, Thomas P. May, International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Hospitality Sub-Committee, W. Aretz, W. A. Briggs Bitumen Co., 3303 Richmond, Philadelphia, Pa.

Better TP Committee Attendance Is Sought

Emphasis will be placed this year on encouraging as great attendance as possible at meetings of the technical practices sub-committees, now scheduled to be held on Monday, March 12, 1951, at the Statler Hotel, New York City, the day preceding formal opening of the 1951 NACE Conference and Exhibition. It has not been understood generally by membership of the association that these meetings are open to all members and others interested in the work being done, and are not exclusively for members of the committees.

Technical Program—

Corrosion Principles Symposium: H. H. Uhlig, Massachusetts Institute of Technology, chairman.

Round Table on General Corrosion Problems, F. L. LaQue, International Nickel Co., Inc., New York, chairman.

Round Table on Pipe Line and Underground Corrosion, R. L. Bullock, Interstate Pipe Line Co., Tulsa, Okla., chairman.

Sam Tour Award

O. B. Ellis, Senior Research Engineer, Armco Steel Corp., Middletown, Ohio has been presented the Sam Tour award for his paper entitled "Effect of Weather on the Initial Corrosion Rate of Sheet Zinc," an ASTM presentation.

Changes in officers, or changes in addresses of officers should be brought to the attention of Central Office by secretaries of NACE regions and sections. Changes will be made as soon as possible in the monthly list "Directory of Regional and Sectional Officers."

Corrosion Problems

Questions and answers for this heading should be submitted in duplicate if possible, addressed to "CORROSION PROBLEMS", National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas. Questions received at the address above above will be sent to E. A. Tice, The International Nickel Co., Inc., N. Y., who is acting editor of the page. All questions will become property of NACE. Questions and replies may or may not be published under this heading and may be answered either by mail directly to the person asking the information, or published under this heading, or both, at the discretion of the editorial staff. Answers to published questions are solicited. Authors of questions will remain anonymous to readers, while authors of answers may remain anonymous if they request it.

QUESTIONS AND ANSWERS

No. 31—At a fueling station for Diesel locomotives, the fuel oil is piped from a 20,000-gallon storage tank through 1800 feet of 6-inch diameter steel pipe to the locomotive. Rust in this line breaks loose and is carried into the fuel tanks of the locomotive where it causes trouble by clogging filters. Is there a method which can be used to prevent corrosion in the 6-inch line which will not have an adverse effect on the fuel? If not, is there an economical material which can be used in place of steel for this pipe line?

ANSWER

There is no certainty that an aluminum alloy seamless pipe would be more expensive than a coated steel pipe line. It is generally estimated that aluminum would cost about twice as much as bare steel, particularly if the service is a low pressure line. There have been several cases brought to our attention, where contamination of the product by steel tubes has justified the use of bare aluminum pipe or tubing. We would be glad to cooperate with the author of this question in regard to cost studies and engineering services — J. B. West, Aluminum Co. of America, 1800 Rhodes-Haverty Bldg., Atlanta 3, Ga.

•

No. 45—What is the best method of controlling carbon dioxide corrosion in steel condensate pipe lines?

ANSWER

This question requires a great deal of detail for a full and complete answer. We refer the author of this question to a paper titled "The Causes and Prevention of Condensate Return Line Corrosion," by R. T. Hanlon, National Aluminate Corp., Chicago, Ill. This was presented at the Midwest Power Conference, April, 1948. (Editor's Note: Presumably copies of this paper are available from subject company).

QUESTIONS

No. 53—How much current will be required to maintain a cathodic protective potential of 0.83 volt at the top of a 20-inch O.D. water well casing 1200 feet deep, the voltage being measured through a copper sulfate half cell?

No. 54—Has there been any experimental evidence to indicate that passivation treatments for stainless steels are effective when the steel is used in aqueous media at temperatures such as 200 to 250 degress C?

Clippings on Corrosion

Extracted from Current Periodicals

GLASS LINED SILO TESTED AND PUT ON THE MARKET

(From Boise, Idaho, *Farmer,* May 18, 1950)

Tests since 1945 of a glass-lined silo trade-named "Harvestore" by the A. O. Smith Corp., Milwaukee, Wis., have been successful to the point the new silo now has been put on the market. The silo is glass-coated inside and out to protect the metal against corrosion and weather. Spoilage elimination also is claimed because the container is airtight.

While no promises as to the life of the silo are made it is expected to outlast wood or concrete.

•

565-MILE PRODUCTS PIPE LINE SALT LAKE CITY TO PASCO, COATED INSIDE AND OUT

(From Boise, Idaho, *Morning Statesman,* May 28, 1950)

The Salt Lake Pipe Line Company expects to complete during the latter part of July a 565-mile, 15,000-barrel-a-day products pipe line between Salt Lake City, Utah, and Pasco, Washington. The line, buried an average of two feet, is coated on the outside and treated with an anti-corrosion material on the inside.

•

RESEARCH GRANT GIVEN

(From Columbus, Neb., *Telegram,* May 3, 1950)

Lincoln, Neb.—Dr. Carl Borgman, dean of faculties at the University of Nebraska, has received a $3500 grant from Research Corporation of New York for fellowship work on metal corrosion.

•

CORROSION FOUND IN GAS LEAK INSPECTION AT PROJECT

(From Omaha, Neb., *Evening World Herald,* May 13, 1950)

Tests made on corrosion of gas mains at North Side housing projects of the Omaha Housing Authority showed some corrosion attributed to electrolytic action, but "nothing serious." The corrosion was described as the result of quality of the earth about the pipe, of stray current from underground electric works, according to O. L. Baublitz and Robert M. Webb, operation engineer consultants.

•

INJECTION WATER TREATED TO LIMIT CORROSION, CLOGGING

(From St. Louis, Mo., *Post-Dispatch,* April 30, 1950)

A full page of pictures showing water-injection operations in use in Illinois oil fields includes one caption stating in part: Air is forced through the water to oxidize iron in water to a precipitate. Further treatment removes impurities by coagulation, flocculation, sedimentation and filtration to prevent corrosion in the injection system and clogging of the oil bearing sandstone far underground.

NEW DESIGN

IN OIL IMMERSED RECTIFIERS

TOP OF CASE

MOLDED NEOPRENE SEAL →

TOP TIE-DOWN FITTING

← SIDE OF CASE
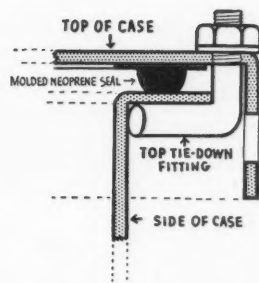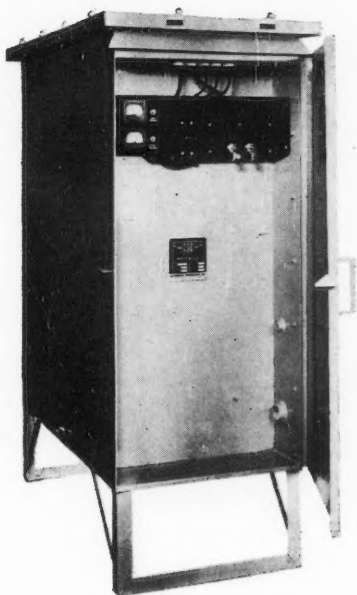
EASY ACCESS FEATURE

Top is quickly removed by loosening nuts and turning tie-down fittings parallel through slots illustrated.

CSC

The Latest and improved features developed for the Corrosion Industry

New design for accessibility incorporating new methods for convenience in installation.

The case is designed for easy accessibility of AC and DC connections.

Individual compartment houses voltage and amperage meters equipped with individual ON—OFF switches and overload magnetic line switch.

Baked enamel finish is standard for all weather resistant housings.

Easy change, 27 voltage output selector taps are located on the panel for convenient adjustment.

Explosion proof models are available for Class 1, Group D, hazardous area operation.

COMPLETE LINE OF AIR COOLED MODELS ALSO AVAILABLE

FOUR WEEKS DELIVERY

CATHODIC SERVICING COMPANY

1024 NORTH OLIE STREET　　　**PHONE 7-5890**　　　**OKLAHOMA CITY, OKLA.**

British Periodical Cites Need for Recognition Of Corrosion Engineer

That there is need for recognition of corrosion engineering in Britain is indicated by the following editorial from *Metal Industry*, March 10, 1950, a British periodical:

Nature—and corrosion certainly is nature in the raw—does not take kindly to being banished into test tubes. The study of corrosion in laboratory tests can be compared with the study of wild animals at the zoo. An investigator of corrosion can always come to the end of his tests, write up his results and draw his conclusions, in the same way as a zoologist studying animals in captivity. Tests involving atmospheric or marine exposure are better, but like Whipsnade or National Park, they are still not the real thing. Unlike the corrosion investigator and the zoologist, the corrosion engineer, like the big game hunter or game warden, is always learning, usually the unexpected. The difference between controlled corrosion tests and corrosion as encountered under actual service conditions is, of course, generally recognized. There might be nothing much in a name, but the use in this country of "corrosion engineer" to refer, as in America, to the man who deals with the practical side of corrosion, would be helpful. Assuming that there are any corrosion engineers in this country, their identification as such could be the first step toward formation of a Society of Corrosion Engineers. There would then be a chance of "Corrosion Engineering," or some such publication, making its appearance. Such a publication would not only provide an opportunity for the much needed recording of the varied experiences of corrosion engineers, but would also see to it that the latter were kept informed of the practical results and implications of laboratory and theoretical work in the field of corrosion. By taking the lead in this way, corrosion engineers would prevent a monopoly by the purely scientific and theoretical aspects of the subject, which under the aegis of corrosion engineering would be made to serve practical purposes, with the purely scientific and theoretical matters and discussion being left to appear elsewhere. Now if only there were some corrosion engineers . . . .

Japan Science Review Now Being Published

"Japan Science Review," Vol. 1, No. 1, March, 1949 has been received by Central Office NACE. The periodical, published quarterly by Association for Science Documents Information, Tokyo Institute of Technology, Ookayama, Meguro-ku, Tokyo, Japan, is in English and contains articles recommended for publication by leading societies associated with the Union of Societies of Engineering. The $7\frac{1}{4}$ x $10\frac{1}{4}$ book, contains over 200 pages, all editorial material. Price is $5 for the volume, No. 2 of which already is in print.

Among the articles of corrosion interest are:

"An Electron Diffraction Study on the Corrosion of Metals," by Shigeto Yamaguchi, Scientific Research Institute, Ltd., Tokyo. American, German, Indian and Japanese references.

"Research on the Surface Technology in Japan," by Makoto Okoshi. Eight Japanese references.

"Roofing Tile Made of Steel Powder Cement," by Minoru Hamada, Tokyo University.

Gas Condensate Well Reprints Are Available

Reprints of the article "Field and Laboratory Tests of Sodium Chromates and Alkalies For Controlling Corrosion in Gas-Condensate Wells," C. K. Eilerts, R. V. Smith, F. G. Archer, Faye Greene and H. C. Hamontre from CORROSION, April, 1950 have been made by and are available from Mutual Chemical Company of America, 270 Madison Ave., New York 16, N. Y. Serial No. 63 has been assigned the reprint, which is an abridged report, plus discussion, of the longer article published serially in WORLD OIL, July-Dec. 1949.

•

Notices of future meetings of NACE subdivisions are carried monthly under the heading "NACE Calendar" in each issue of CORROSION magazine. Notices for this column should be sent to Central Office.
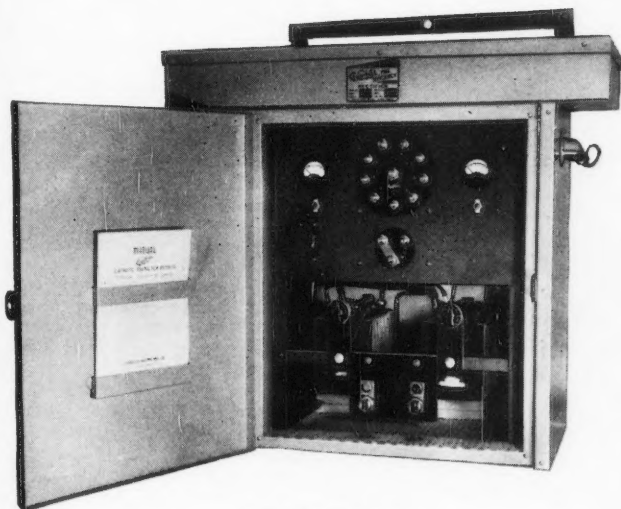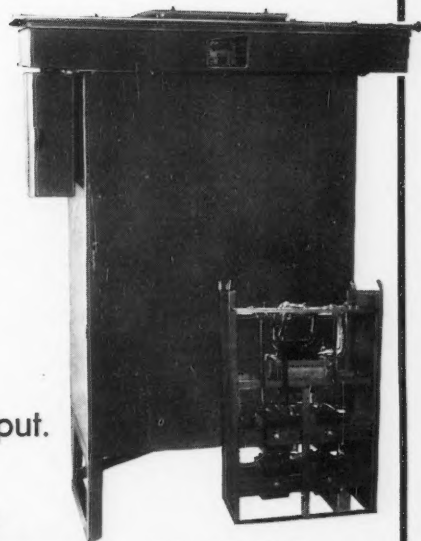
BOOK REVIEWS

SOIL CORROSION STUDIES, 1946: FERROUS METALS AND ALLOYS. Research Paper RP2057. By Irving A. Denison and Melvin Romanoff, National Bureau of Standards. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 32 pp, 8 x 10¼, 15 Cents.
Results of measurements of corrosion made on a variety of wrought and cast ferrous materials after exposure in different soil conditions for periods up to 14 years. The magnitude and progress of corrosion with respect to weight loss and pitting are interpreted in relation to soil properties.

•

SOIL-CORROSION STUDIES, 1946 and 1948: COPPER ALLOYS, LEAD AND ZINC. Research Paper RP2077. By Irving A. Denison and Melvin Romanoff, National Bureau of Standards. Superintendent of Documents, Washington, D. C. 32 pp, 8 x 10¼, 20 Cents.
Results of measurements of corrosion of copper, lead and zinc and certain alloys of these metals after exposure to different soil conditions for a maximum of 14 years. The magnitude and progress of corrosion with respect to weight loss and pitting is intepreted in relation to the composition of materials and the properties of the soils at test sites. Comparative data are given for the corrosion of plain iron and steel, copper, lead and zinc in typical soil environments.

•

CHEMICAL ANALYSIS OF ALUM-INUM. Aluminum Company of America. 150 pp, 5½ x 8½, wire bound, paper back. Aluminum Company of America, Pittsburgh 19, Pa. Per Copy, $1.00.
Third Edition of this widely-used manual which gives in detail the procedures for chemically analyzing aluminum and its alloys and contains many methods developed and standardized by Alcoa's analytical chemists under the direction of H. V. Churchill. Procedures are given for determination of 40 elements.

Useful Additions to NACE Files Listed

Useful additions to the NACE reference files recently received include the following:

LEAD—Catalog No. 47C, National Lead Company Products, 111 Broadway, New York 6, N. Y. Containing sections on lead pipe, sheet, lined equipment, acid recovery equipment, lead pipe for water service, fittings, solder, flues, caulking, zinc base alloys, pewter, block tin products, painting materials and general information data.

COATINGS — Ceilcote Industrial Protective Coatings, The Ceilcote Company, Rockefeller Bldg., Cleveland, Ohio. Products and applications of products for protection of metal and concrete surfaces against corrosion are detailed. Data on corrosion-resistant cements, aluminum coatings, brush coatings, primer, fume duct linings and other products are given.

COATINGS—Reference list of metal protective and paint bonding chemicals and processes of American Chemical Paint Company, Ambler, Pa.

COATINGS — "Where Tars Come From," Koppers Co., Tar Products Division, Pittsburgh 19, Pa. A summary of the methods of producing coal tar coatings.

COPPER—Anaconda Copper Tubes for Industrial Applications, The American Brass Company, Waterbury 88, Conn. Contains data on copper tubes used in process industries, pulp and paper mills, breweries, wineries and distilleries, sugar processing, refrigeration and air conditioning, industrial heating, air, lubricating and hydraulic lines, connections, fittings, accessories, sizes, methods procedures and engineering data on various kinds of copper and copper-alloy tubes.

STEEL—Mayari R, Bethlehem's high strength, corrosion resisting steel is described in Catalog 259, Bethlehem Steel Co., Bethlehem, Pa. Listed are uses, comparisons, features, corrosion resistant characteristics, weight, abrasion resistance, welding, workability.

ALLOY AND LININGS — A. O. Smith Corp., Milwaukee, Wis.: Smithway Vessels, a catalog of alloy, alloy lined, clad and glass lined vessels. Field Assembly of Pressure Vessels the Smithway, giving details of methods used. Multi-Layer Manufacture and Assembly, building thick-walled pressure vessels. Reprints—A New Method of Storing Pulp Cooking Liquors for the Paper Industry, from CORROSION, August, 1949. Modified Type 405 Stainless Iron, reprinted from METAL PROGRESS, July, 1947. Paper Industry Benefits from A. O. Smith Research and Engineers, from TAPPI, March 1950 and CORROSION, November, 1949.

NACE CALENDAR

LOS ANGELES SECTION—August 16.

CLEVELAND SECTION—Week of September 24.

METROPOLITAN NEW YORK SECTION—September 20.

NORTH EAST REGION—September 13.

PHILADELPHIA SECTION—September 13.

•

Corrosion Division of Electrochemical Society Schedules Program

The Corrosion Division of The Electrochemical Society is making plans for meeting during the society's convention at Buffalo, October 12-15, 1950. One session of the meeting is to be devoted to measurement and interpretation of electrode potentials and other electrical properties of metals in relation to corrosion processes. Papers for this program are solicited.

Papers of general interest on corrosion also are invited because additional sessions are planned to the extent time is available. Titles and abstracts of papers should be submitted to the Division Chairman, I. A. Denison, National Bureau of Standards, Washington 25, D. C., vice-chairman, J. M. Pearson, Sun Physical Laboratory, Bishop Hollow Rd., Newton Square, Pa. or the secretary-treasurer, Norman Hackerman, Department of Chemistry, University of Texas, Austin, Texas.

•

Digests of Naval Forum Papers Are Reprinted

Digests of the papers presented at the Office of Naval Research "Forum on Corrosion Research" compiled into a report and reprinted from The Journal of The Electrochemical Society, Vol. 97, No. 4, (1950) April, are scheduled to be available for distribution the latter part of August. Requests for copies should be addressed to Materials Branch, Office of Naval Research, Navy Department, Washington 25, D. C. The review was prepared by J. J. Harwood and Fred Schulman of the Office of Naval Research, Department of the Navy, Washington 25, D. C.

•

Flow Plan Symbols Practice Recommended

Instrument Society of America has issued as ISA RP5.1, a tentative recommended practice "Instrumentation Flow Plan Symbols" to its members. Prices are up to 20 copies $1 each; larger quantities at lesser unit prices. Obtainable from ISA National Office, 921 Ridge Ave., Pittsburgh 12, Pa.

NEW AND REINSTATED MEMBERS
(Changes Through June 23, 1950)

ALABAMA

WRIGHT, E. A., Wolverine Tube Div., Decatur, Ala.

ARKANSAS

SHEETS, EARL T., Oklahoma Glass Fiber Corp., Box 281, Newport, Ark.

CALIFORNIA

FOURAKER, ROBERT W., Richfield Oil Corp., P. O. Box 787, Wilmington, Cal.

SNIDER, HENRY I., Amercoat Corp., 4809 Firestone Blvd., Southgate, Cal.

STALKER, MARION H., Andrew Brown Co., 5431 S. District Blvd., Los Angeles, Cal.

CONNECTICUT

DOUGLASS, DWIGHT, The Hartford Electric Light Co., 266 Pearl St., Hartford 15, Conn.

FULLMAN, JAMES B., Scofieldtown Rd. and Woodley Lane, Stamford RD 2, Conn.

MEYER, FREDERICK R., Southern New England Tel. Co., Administration Bldg., 227 Church St., New Haven, Conn.

FLORIDA

PRIME, JOSEPH B., JR., Florida Power & Light Co., Box 3100, Miami 30, Fla.

INDIANA

BERG, SIGVALD L., 400 Center St., Hobart, Ind.

MENTZEL, SIGMUND T., Carnegie Illinois Steel Corp., 1 N. Broadway Ave., Gary, Ind.

MULLINS, SIDNEY O., Carnegie-Illinois Steel Corp., Buchanan St., Gary, Ind.

ILLINOIS

BRUSE, WM. E., Illinois Tool Works, 1001 Grace, Elgin, Ill.

DUNAGAN, GEORGE M., The Texas Co., Route 2, Salem, Ill.

MIKESELL, WILLIAM H., United Chromium, Inc., 208 S. LaSalle St., Chicago, Ill.

MASSACHUSETTS

NEWLAND, STEWART H., Electro Rust-Proofing Corp. (N.J.), 1262 Commonwealth Ave., Boston 34, Mass.

SEMPLE, FRANK B., 21 Prospect Ave., Swampscott, Mass.

MICHIGAN

NICHOLLS, ALFRED, Burroughs Adding Machine Co., 6071 Second Ave., Detroit 32, Mich.

ARMSTRONG, CLIFFORD B., JR., Wyandotte Chemicals Corp., 1609 Biddle Ave., Wyandotte, Mich.

MISSISSIPPI

SWINDOLL, ROBERT E., United Gas Corp., P. O. Box 1138, Jackson, Miss.

MISSOURI

BOST, PAUL L., Koppers Co., Inc., 4000 Bingham Ave., St. Louis, Mo.

McCLUSKEY, FRANCIS J., James R. Kearney Corp., 4236 Clayton Ave., St. Louis, Mo.

SERENCO, HARVEY, Upper Mississippi Valley Div., U. S. Corps of Engineers, 755 New Federal Bldg., St. Louis 1, Mo.

OHIO

BUTLER, C. A., JR., Diamond Alkali Co., P. O. Box 699, Painesville, Ohio.

KLOPP, EDWARD M., Cleveland Heater Co., 2310 Superior Ave., Cleveland, Ohio.

THURRELL, ROGER F., Aluminum Company of America, 801 Enquirer Bldg., Cincinnati 2, Ohio.

OKLAHOMA

GETTYS, WILBUR H., Phillips Petroleum Co., Engineering Dept., Bartlesville, Okla.

PENNINGTON, LOUIS E., Reynolds Metals Co., 310 Thompson Bldg., 20 E. 5th St., Tulsa 3, Okla.

PENNSYLVANIA

GILLIAMS, FRANCIS B., Atlantic Refi* Co., 3144 Passyunk Ave., Philadelphia.

SPENCER, S. F., Keystone Shipping Co., 1.15 Chestnut St., Philadelphia 7, Pa.

TEXAS

BLANDA, PETER, Kewanee Oil Co., P. Box 848, Crane, Texas.

BLILER, ROY K., Service Engineers, Inc., 709 1st National Bank Bldg., Ft. Worth, Texas.

BOOTH, ROBERT C., Shell Oil Co., 2107 Shell Bldg., Houston, Texas.

BRESLIN, JACK D., Formica Co., P. O. Box 8188, Houston, Texas.

CHRISTIAN, JAMES W., Route No. 1, Box 39, Alta Loma, Texas.

COLE, RALPH R., Paul G. Bentley Co., 3612 Potomac, Dallas 5, Texas.

DAVIS, CHARLES T., JR., 1621 Missouri, Houston 6, Texas.

HUCKLEBERRY, S. A., Dowell Inc., 1333 York St., Corpus Christi, Texas.

JAMES, WM. D., Southern Union Gas Co., 401-12th St., Port Arthur, Texas.

LEDFORD, ROBERT C., Marine Gathering Co., The Oil & Gas Bldg., Houston, Texas.

MONTAGUE, DONALD E., 3001 St. Bernard, Houston, Texas.

NEW JERSEY

TALBOTT, DANIEL W., Copper Alloy Foundry Co., Ramsay & Bloy St., Hillside, N. J.

NEW YORK

BISSELL, CARL H., Crouse-Hinds Co., Syracuse, N. Y.

DUNN, EDGAR F., Whitehead Metal Products Co., Inc., 254 Court, Buffalo 2, N. Y.

GERBEN, MAX, Gerben Contracting Co., Inc., 36-11 Ditmars Blvd., Long Island, N. Y.

POWER, PIERCE H., Paragon Paint & Varnish Corp., 5-49 46th Ave., Long Island City 1, N. Y.

SHIELDS, JAMES E., Alox Corp., P. O. Box 556, Niagara Falls, N. Y.

FOREIGN

MOYAR, ROBERT E., Standard Vacuum Petroleum Maatschappij, Pendopo, Sumatra, Indonesia.

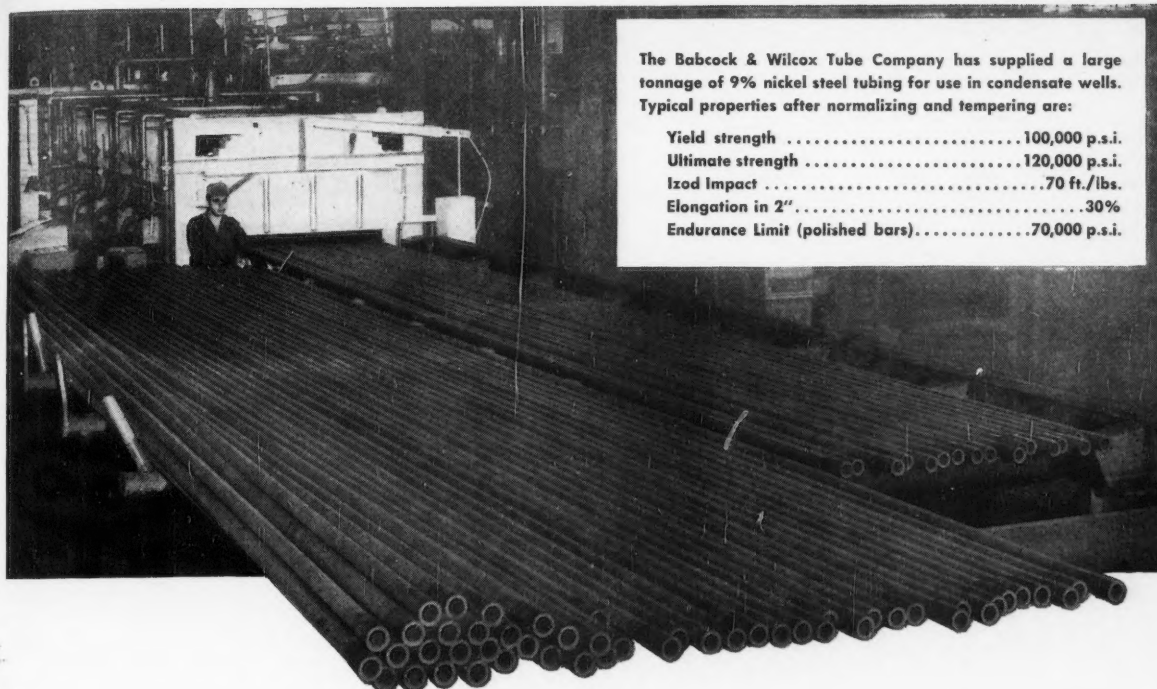TOWNE, ROBERT I., Creole Petroleum Corp., Pipe Line Section, Apartado 889, Caracas, Venezuela.

CHANGES OF ADDRESS
(Old Address Folows New Address in Parenthesis)

ALABAMA

GAMBLE, CHAS. B., JR., Alabama Gas Corp., Watts Bldg., Birmingham 3, Ala. (Gamble, Chas. B., Alabama Gas Corp., Watts Bldg., Birmingham 3, Ala.).

YELDELL, J. W., General Supt., Southern Natural Gas Co., P. O. Box 2563, Birmingham 2, Ala. (Supt. of Operations, Southern Natural Gas Co., P. O. Box 2563, Birmingham 2, Ala.).

Ch

Econ
from

Ex
of the
Tub
tant
Mor
made

Ad
exce
dow

As
toge
this

... n

TH

Changes of Address—

(Continued From Page 14)

ARIZONA

CHAPMAN, WALTER H., 6015 S. 7th Ave., Phoenix, Ariz. (108 W. 9th St., Casa Grande, Ariz.).

CALIFORNIA

DEGENHART, THURLO E., 1058 Calaveras Way, Vallejo, Cal. (Mare Island Naval Shipyard, Bldg. 47, Public Works Design, Vallejo, Cal.).

DORSEY, JOSEPH S., Southern California Gas Co., Box 3249, Terminal Annex, Los Angeles 54, Cal. (1216 No. La Presa Drive, San Gabriel, Cal.).

HENDRICKSON, DAVID, East Bay Municipal Utility District, 512 Sixteenth St., Oakland, Cal. (H. A. Knudsen, East Bay Municipal Utility District, 512 Sixteenth St., Oakland, Cal.).

KETCHAM, BROWER, 915 Franklin St., San Francisco 9, Cal. (Brower Ketcham Distributor, 915 Franklin St., San Francisco, Cal.).

KLAUBER, L. M., Chairman of the Board, San Diego Gas and Electric Co., Box 1831, San Diego 12, Cal. (KLAUBER, L. M. Pres., San Diego Gas and Electric Co., Box 1831, San Diego 12, Cal.).

POMEROY, RICHARD, Montgomery & Pomeroy, 660 So. Fair Oaks Ave., Pasadena 2, Cal. (660 So. Fair Oaks Ave., Pasadena 2, Cal.).

ROBESON, RALPH M., General Petroleum Corp., 621 So. Flower St., Los Angeles, Cal. (General Petroleum Corp., 108 W. Second St., Los Angeles, Cal.).

SCOTT, HAROLD H., 1506 Brown St., Martinez, Cal. (2820 Leslie St., Martinez, Cal.).

SIMMONS, EDWARD E., JR., 455 S. Oakland Ave., Pasadena 5, Cal. (Fluid Log Corp., 455 S. Oakland Ave., Pasadena 5, Cal.).

STEPHAN, DEAN E., Chicago Bridge & Iron Co., 612 S. Flower St., Rm. 834, Los Angeles 14, Cal. (Chicago Bridge & Iron Co., 612 S. Flower St., Room 458, Los Angeles 14, Cal.).

TODHUNTER, HAROLD A., 5501 Bershire Dr., Los Angeles 32, Cal. (Dept. of Water & Power, 207 S. Broadway, Los Angeles, Cal.).

COLORADO

ABBOTT, CHARLES B., Colorado Interstate Gas, Box 1087, Colorado Springs, Colo. (ABBOTT, CHARLES B., Colorado Interstate Gas, Box 1087, Colorado Springs, Colo.).

BARKOW, CARL W., Anvil Pts. No. 50, Rifle, Colo. (U. S. Bureau of Mines, Oil Shale Demonstraton Plant, Rifle, Colo.).

DISTRICT OF COLUMBIA

LEAS, A. ROBERT, Williams Bros. Corp., 1026 17th St. N. W., Washington, D. C. (1026 17th St. N. W., Washington, D. C.).

GEORGIA

BARRETT, ROBERT C., c/o Chemical Products Corp., Cartersville, Ga. (Koppers Co., Inc., Woodward, Ala.).

TAIT, EMMITTE P., Alloy Steel Products Co., 333 Candler Bldg., Atlanta, Ga. (House 123, Village I, Sheffield, Ala.).

ILLINOIS

LYON, JOHN A. M., DR., Dept. of Electrical Engineering, Northwestern University, Evanston, Ill. (Dept. of Electrical Engr., Techn. Institute, Northwestern University, Evanston, Ill.).

MOYER, GEORGE H., 10505 S. Maplewood Ave., Chicago 43, Ill. (Standard Varnish Works, 10505 S. Maplewood Ave., Chicago 43, Ill.).

PACE, ANDERSON, JR., Bauer & Black, 2500 S. Dearborn, Chicago, Ill. (2500 S. Dearborn, Chicago, Ill.).

ROBERTS, R. G., The Barrett Div., Allied Chem. & Dye Corp., 205 W. Wacker Dr., Chicago 6, Ill. (The Barrett Div., Allied Chem. & Dye Corp., 1400 Lake Shore Dr., Chicago 10, Ill.).

SERBULA, STEVE, JR., Rust-Oleum Corp., 1837 N. Natchez Ave., Chicago 35, Ill. (1837 N. Natchez Ave., Chicago 35, Ill.).

WARNER, CLARENCE J., The Leader Iron Works Co., 2100 N. Jasper St., Decatur, Ill. (The Colonial Iron Works Co., 17643 St. Clair Ave., Cleveland, Ohio).

INDIANA

MARTIN, D. S., Citizens Gas & Coke Utility, 49 S. Penn St., Indianapolis, Ind. (Citizens Gas & Coke Utility, 330 West 9th St., Indianapolis, Ind.).

LOUISIANA

KUHN, ROBERT J., Consulting Engineer, 1643 Octavia St., New Orleans 15, La. (Consulting Engineer, 2724 Octavia St., New Orleans 15, La.).

PICARAZZI, JOSEPH J., Cities Service Refg. Corp., Tutwiler Refinery, Lake Charles, La. (1908 Woodruff St., Lake Charles, La.).

VIDOVIC, PAUL P., 1742 Pickett Ave., Baton Rouge, La. (Metal Goods Corp., 432 Julia St., New Orleans, La.).

MARYLAND

DWYER, T. J., Con. Gas Elec. Light & Pwr. Co. of Balt., Lexington Bldg., Baltimore 3, Md. (Con. Gas Elec. Light & Pwr. Co. of Balt., 2nd Floor Front St. Bldg., Baltimore 3, Md.).

WRIGHT, HOWARD P., Baltimore & Ohio RR, 609 B & O Bldg., Baltimore 1, Md. (Baltimore & Ohio RR, B & O Bldg., Baltimore & Charles, Baltimore 1, Md.).

MICHIGAN

BACHMAN, PAUL W., c/o The Davison Chemical Corp., Baltimore 3, Md. (c/o the Davison Chemical Corp., Baltimore 3, Md.).

BAKER, RALPH D., R. D. Baker Contractor, Inc., Box 187, Redford Station, Detroit 19, Mich. (National Lead Co., 111 Broadway, New York, N. Y.).

O'BRIEN, THOS. W., Ray D. Baker Contractor, Inc., Box 5155, South Field Station, Detroit 35, Mich. (R. D. Baker Contractor, Inc., Box 187, Redford Station, Detroit 19, Mich.).

WALKER, HENRY S., Director of Research, The Detroit Edison Co., 2000 Second Ave., Detroit 26, Mich. (WALKER, HARRY S., Director of Research, The Detroit Edison Co., 2000 Second Ave., Detroit 26, Mich.).

WIEGELE, T. W., Vice President & Engineer, Michigan Consolidated Gas Co., 415 Clifford St., Detroit 26, Mich. (Gas Engineer, Michigan Consolidated Gas Co., 415 Clifford St., Detroit 26, Mich.).

NEBRASKA

OLSON, THEODORE W., Natural Gas Pipeline Co. of America, P. O. Box 486, Beatrice, Neb. (P. O. Box 486, Beatrice, Neb.).

SMITH, LYLE R., Good-All Electric Mfg. Co., 112 W. First St., Ogallala, Neb. (Good-All

Changes of Address—

(Continued From Page 16)

Electric Mfg. Co., 112 Main St., Ogallala, Neb.).

NEW JERSEY

GUERRY, WM. A., 242 Willow Drive, Little Silver, N. J. (Apt. A, Warwick Apartments, 42 Pinkney Rd., Red Bank, N. J.).

MATHERS, W. D., 643A Bruce St., Ridgefield, N. J. (Aluminum Co. of America, 643A Bruce St., Ridgefield, N. J.).

PRIOR, JOSEPH E., 73 N. Evergreen Ave., Woodbury, N. J. (Res. & Dev. Lab., Socony-Vacuum Oil Co., Inc., Paulsboro, N. J.).

SHENTON, F. GEORGE, Route 1, Monroeville, N. J. (Research & Development Labs., Socony-Vacuum Oil Co., Inc., Paulsboro, N. J.).

STAPLES, WM. R., Carpenter Steel Co., Union, N. J. (Carpenter Steel Co., 24 California St., San Francisco, Cal.).

WEST, CHARLES HOWARD, 82 De Hart Place, Elizabeth, N. J. (Standard Oil Development Co., Esso Engineering Dept., P. O. Box 121, Linden, N. J.).

NEW YORK

PROSKOWITZ, SEYMOUR, 866 Hunts Pt. Ave., Bronx 59, New York. (2302 Wichita St., Houston 4, Texas).

TIBBETTS, E. F., The Lummus Co., 385 Madison Ave., New York 17, New York (The Lummus Co., 420 Lexington Ave., New York, N. Y.).

OHIO

FERGUS, D. J., Rickwell Corp., Barberton, Ohio (Cleveland Heater Co., 2310 Superior Ave., Cleveland, Ohio).

FUNK, F. W., Vice President, Ohio Edison Co., 47 N. Main St., Akron 8, Ohio (Ohio Edison Co., 47 N. Main St., Akron 8, Ohio).

KRETSCHMER, WM. J., 3140 Indianola Ave., Columbus 2, Ohio (Columbia Engineering Corp., 3140 Indianola Ave., Columbus 2, Ohio).

MALCOM, V. V., Special Industries Dept., The Philip Carey Mfg. Co., Lockland, Cincinnati 15, Ohio (Industrial Sales, The Philip Carey Mfg. Co., Lockland, Cincinnati 15, Ohio).

McILRATH, SAMUEL W., 715 Lucille Ave., Painesville, Ohio (Diamond Alkali Co., 715 Lucille Ave., Painesville, Ohio).

SANDEL, WALTER J., 1242 Hall Ave., Lakewood 7, Ohio (Coatings for Industry, Inc., 1242 Hall Ave., Lakewood 7, Ohio).

OKLAHOMA

LIGGETT, ERNEST J., Johns-Manville Sales Corp., 1701 E. 7th St., Tulsa 1, Okla. (1701 E. 7th St., Tulsa, Okla.).

PENNSYLVANIA

DAVIS, F. W., 1430 Widener Place, Philadelphia 41, Pa. (E. B. Badger & Sons Co., 75 Pitts St., Boston 4, Mass.).

SANTSCHI, WILLIAM H., 626 E. 10th Ave., Tarentum, Pennsylvania (Engineering Experiment Station, Columbus 10, Ohio).

SWENSSON, STUART J., American Hot Dip Galvanizers Ass'n, Inc., 2311 First Nat'l Bank Bldg., Pittsburgh 22, Pa. (American Hot Dip Galvanizers Ass'n, Inc., 1611 First Nat'l Bank Bldg., Pittsburgh 22, Pa.).

TRACEY, EDWARD J. J., JR., The Pennsylvania State College, University Club, State College, Pa. (University Club, State College, Pa.).

WELKER, JOHN W., Milton Roy Co., 1300 E. Mermaid Lane, Philadelphia 18, Pa. (Milton Roy Pumps, 1300 E. Mermaid Ave., Philadelphia 18, Pa.).

Changes of Address—

(Continued From Page 18)

TENNESSEE

LAMBERT, FRANK J., JR., Carbide & Carbon Chemicals Div., Union Carbide & Carbon Co., Y-12 Plant, Bldg. 9766, Oak Ridge, Tenn. (Carbide & Carbon Chemicals Corp., Y-12 Plant, Bldg. 9766, Oak Ridge, Tenn.).

LEHMANN, FREDERICK A., Carbide & Carbon Chem. Div., Union Carbide & Carbon Co., Oak Ridge, Tenn. (Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.).

TEXAS

BELL, S. J., American Petroleum Co., Petroleum Bldg., Houston 2, Texas (G. O. Irvine, American Petroleum Co., Petroleum Bldg., Houston 2, Texas).

BRUYERE, WM. H., Pan American Pipe Line Co., 1413 Niels Esperson Bldg., Houston 2, Texas (J. R. Wait, Jr., Pan American Pipe Line Co., 12th Floor, Mellie Esperson Bldg., Houston 2, Texas).

CAHILL, JOE L., 5006 Calhoun Rd., Houston, Texas (c/o Lamar Hotel, Houston, Texas).

CASTLE, HARRY, JR., P. O. Box 1425, Jacksonville, Texas (United Gas Corp., 810 Lamar St., Wichita Falls, Texas).

COATES, CHARLES, Operating Vice President, Tennessee Gas Transmission Co., P. O. Box 2511, Houston 1, Texas (Assistant to Vice President, Tennessee Gas Transmission Co., P. O. Box 2511, Houston 1, Texas).

DRAGICS, EARL V., Owens-Corning Fiberglas Corp., Room 1310, 1114 Texas Ave., Houston 2, Texas (Owens-Corning Fiberglas Corp., 629 M & M Bldg., Houston 2, Texas).

FRASCH, H. H., 3921 Normandy St., Dallas, Texas (National Carbon Co., Inc., Wilson Bldg., 1621 Main St., Dallas 1, Texas).

GREBE, H. A., Grebe & Doremus Process Co., 4601 Stanford, Houston, Texas (4601 Stanford, Houston, Texas).

HART, PORTER, The Dow Chemical Co., 1410 W. 4th St., Freeport, Texas (The Dow Chemical Co., Freeport, Texas).

HEINEMANN, GUSTAVE, 1013 Oak Park Ave., Corpus Christi, Texas (Southern Alkali Corp., 1013 Oak Park Ave., Corpus Christi, Texas).

HENRY, R. E., Pipe Line Service Corp., P. O. Box 1244, Longview, Texas (P. O. Box 1244, Longview, Texas).

HODSON, FRED W., Johns-Manville Sales Corp., P. O. Box 2366, Corpus Christi, Texas (Johns-Manville Sales Corp., P. O. Box 8217, Houston 4, Texas).

KING, GLENN W., Glenn W. King Co., 4101 San Jacinto, Houston 4, Texas (4101 San Jacinto, Houston 4, Texas).

KUHN, CYRIL D., Tennessee Coal, Iron & R. R. Co., Box 159, Houston, Texas (TCI & RR, Box 159, Houston, Texas).

LINGLE, ROBERT J., Room 309 Shell Bldg., Houston, Texas (Room 319, Shell Bldg., Houston, Texas).

McCLUGHAN, JOSEPH, 7420 Moline St., Houston 17, Texas (Converted Rice, 7420 Moline St., Houston 17, Texas).

MOORE, JACK M., Dowell Inc., Box 1858, Midland, Texas (Box 1858, Midland, Texas).

ROSS, GEORGE T., Houston Natural Gas Corp., Box 1188, Houston 1, Texas (4121 Ayres, Corpus Christi, Texas).

SCHMUCK, HOWARD K., JR., 5111 Inker St., Houston 7, Texas (Haynes Stellite Div., Union Carbide & Carbon Corp., 6119 Harrisburg Blvd., Houston 11, Texas).

SCOTT, THOMAS W., 707 N. Alleghaney, Odessa, Texas (The Parkersburg Rig & Reel Co., 532 West Pearl St., Odessa, Texas).

SNEDAKER, DELBERT G., P. O. Box 7119, Houston 8, Texas (1817 Isabella, Apt. 1, Houston, Texas).

UBBEN, JAMES E., Box 368, Garland, Texas (Emsco Derrick & Equipment Co., 7626 Denton Dr., Dallas, Texas).

VOGEL, ALFRED J., Box 296, Andrews, Texas (Fuhrman Petroleum Corp., First Nat'l Bank Bldg., Midland, Texas).

WIMER, CHARLTON J., Wimer Engineering Co., 2601 Canton St., Dallas 1, Texas (Wimer Engineering Co., 711 Reserve Life Bldg., Dallas 1, Texas).

ZINSER, A. L., Zinser Chemical Engineering Co., Route 4, Box 388, Austin, Texas (Zinser Chemical Engineering Co., Route 4, P. O. Box 388, Austin, Texas).

UTAH

ROZELLE, W. W., Utah Oil Refining Co., P. O. Box 898, Salt Lake City, Utah (P. O. Box 898, Salt Lake City, Utah).

WEST VIRGINIA

VAN DELINDER, L. S., Carbide & Carbon Chemicals Div., Union Carbide & Carbon Corp., South Charleston, W. Va. (Carbide & Carbon Chemicals Corp., South Charleston, W. Va.).

WISCONSIN

DIECKS, A. NORMAN, Apt. 417, 3128 W. Wisconsin Ave., Milwaukee 8, Wis. (c/o Geuder, Paeschke & Frey Co., 324 N. 15th St., Milwaukee, Wis.).

FOREIGN

DALTON, GORDON M., 20 Wilgar Rd., Toronto, Canada (Canadian Westinghouse Co., Ltd., 286 Sanford St., Hamilton, Ontario, Canada).

NORWOOD, VINCENT M., Canadian Oil Companies, Ltd., P. O. Box 600, Petrolia, Ontario, Canada (P. O. Box 600, Petrolia, Ontario, Canada).

STOBAUGH, ROBERT B., JR., c/o Creole Petroleum Corp., Caripito, Monagas, Venezuela, S. A. (Esso Standard Oil Co., P. O. Box 551, Baton Rouge, La.).

NEW NACE CORPORATE MEMBERS

New corporate members added in the interval June 15-July 15, 1950, by the National Association of Corrosion Engineers are:

EMSCO DERRICK & EQUIP. CO.
Los Angeles, Cal.
George W. Whiting, Representative

GRANITE CITY STEEL COMPANY
Granite City, Ill.
Geo. A. Holtzscher, Jr., Rep.

KAISER STEEL CORPORATION
Fontana, California
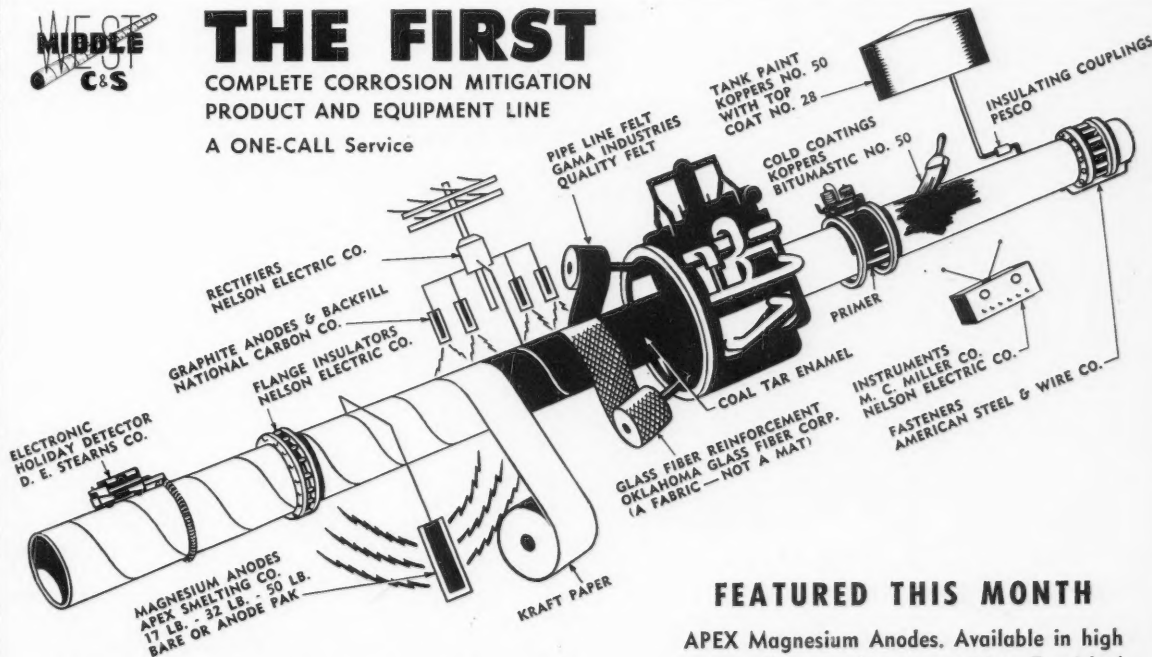*Richard Aubrey, Representative*

UNITED FRUIT COMPANY
Boston, Mass.
Hartley Rowe, Representative

NEW PRODUCTS —Materials—Service—Literature

Ampco Aluminum Bronzes, available in various forms for use in handling low or high temperature corrosives of the acid or oxidizing type and for handling salt or contaminated water have high tensile strength (60,000 to 110,000 psi) and hardness (70 Rockwell "B" to 35 Rockwell "C") and elongation up to 45 percent, according to the manufacturers, Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis. Copies of Bulletin PI-1 are available on request for those who wish complete information about these materials.

Bisonite-M, a solution of inert thermal-plastic resins which have been combined under heat and pressure to form a coating resistant to most strong acids, salts and alkalis is manufactured by the Bisonite Company, Inc., 128 Lakeview Ave., Buffalo 1, N. Y. Technical data sheets supplied by the company state the material is tough, abrasion resistant, flexible, non-porous and waterproof and when properly dried has high dielectric strength. Used with Bisonite Primer high adhesion is claimed on properly prepared surfaces. Soluble in only a very few hydrocarbons the material will withstand temperatures up to 180 degrees F. Numerous uses for the material are listed.

Sulfuric Acid and other highly corrosive fluids may be handled safely in a Hills-McCanna valve which includes a Bakelite polyethylene plastic diaphragm. All concentrations of sulfuric acid, at temperatures up to 125 degrees F, at a maximum of 10 percent excess sulfur trioxide may be handled safely by the valve. Sizes available are ½, 1, 1½, 2 and 3-inch, flanged or screwed ends of many materials with various operating mechanisms. Further information may be secured from Hills-McCanna Company, 3025 North Western Ave., Chicago 18, Ill.

"Economical Corrosion Control for Distribution Systems," a publication of Dowell Incorporated, Tulsa, Oklahoma, gives details on the prevention of corrosion of gas and water distribution systems through the use of currents imposed by magnesium anodes.

Atlas Mineral Products Company's complete line of chemical construction materials including corrosion-proof linings, cements, acid-proof brick and tile, and corrosion-proof coatings and floors is described in a new General Bulletin MCC No. 1, available on request from 42 Walnut Street, Mertztown, Pa.

Air Line Pressure pumps for use in transferring corrosives from stainless steel containers, with either lead or Saran tubes—the only part of the pump that comes in contact with the liquid being transferred—are available from General Scientific Equipment Co., 1015 Packard Bldg., Philadelphia 2, Pa.

Surfamax Filters, a product of Micro Metallic Corp., Brooklyn, New York, are described in a booklet available on request from the company's offices, 193 Radford St. The booklet tells advantages, uses, properties and water and air flow characteristics of the filters.

Zinc Die Castings with interlocked elements, such as chains can be made continuously or to predetermined lengths by a process developed by Gries Reproducer Corp., 780 East 133rd St., New York 54, N. Y.

Vibroground Model No. 263, a 9½ lb. instrument for measuring soil, anode and circuit resistances in ranges 0-1, 0-10, 0-100 and 0-1000 ohms, is powered by eight flashlight batteries, with a circuit employing a synchronous self-rectifying vibrator having an output of 125 volts. Resistance measurements can be made by the 2, 3 or 4-electrode methods. Manufacturers say readings are unaffected by resistance of auxiliary prods or leads, stray currents, and accuracy is based on calibrated resistance rather than meter movement. Further information may be had from Associated Research, Inc., 3750 W. Belmont Ave., Chicago 18, Ill.

"Calgon Stabilizes Dissolved Iron and Manganese" is the title of a new folder
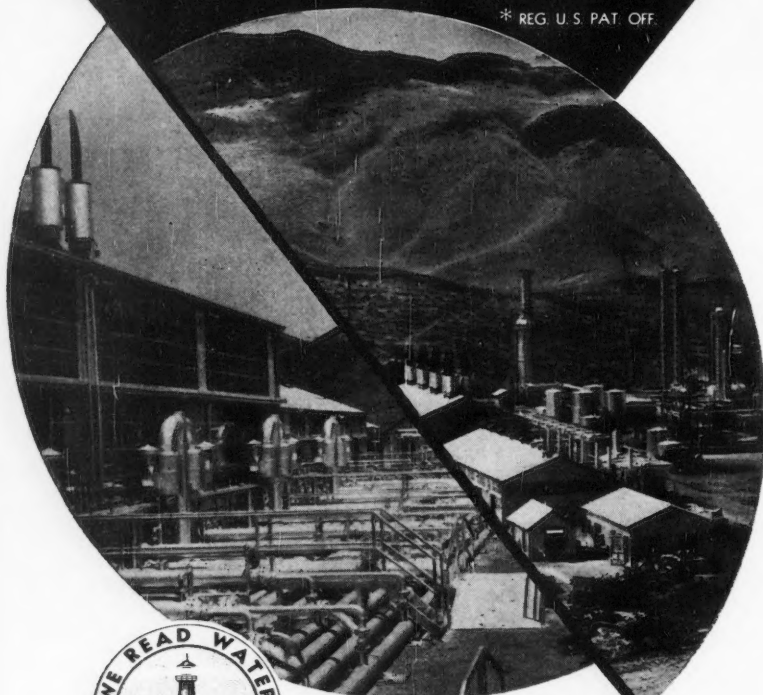
issued by Calgon, Inc., giving details of "threshold treatment" whereby minute amounts of Calgon are continuously fed into a water stream where iron or manganese fouling is a problem. Chlorination is recommended where bacteria constitute part of the fouling problem, because Calgon alone will not prevent iron deposition resulting from bacterial action. Copies are available from the company's offices in the Hagan Building, Pittsburgh, Pa.

"Dryply" glass cloth or mat impregnated with a polyester compound is being used for the production of many parts formerly formed of metal. The material is a product of Flexfirm Products, El Monte, Cal.

Inconel hot-rolled in "T" sections now is being produced at the Huntington, W. Va., works of the International Nickel Co., Inc. Primary purpose of the form is to provide manufacturers of furnaces and other high temperature equipment with ready-made and uniform structural parts. The shapes also can be poduced in nickel and Monel when the tonnage makes it economical.

High Nickel Alloys are described in two new technical bulletins issued by Technical Editor, The International Nickel Co., Inc., 57 Wall St., New York, N. Y. Both are 24 pages and contain charts, tables on compositions and properties, working instructions and other information of technical nature. Technical Bulletin T-7, entitled "Engineering Properties of Inconel" in addition to information on Inconel contains material on Cinconel "X." Technical Bulletin T-9 deals with the engineering properties of "K" Monel and "KR" Monel.

Portable, Light Weight, magnetic particle inspection of material in the field for fatigue and corrosion cracks, weld cracks and other defects is possible with the KH-05 Magnaflux unit, which requires only a 110 volt AC line to give AC or DC magnetization at 500 magnetizing amperes, Magnaglo, using fluorescent magnetic particles, also may be used with the unit. Further information and descriptive literature may be obtained from Magnaflux Corp., 6900 Northwest Highway, Chicago 31, Ill.

Twelve Percent chromium alloy steel castings for use in gas-condensate wells has reduced severe corrosion losses according to Warden F. Wilson, general sales manager for Lebanon Steel Foundry, Lebanon, Pa.

Copies of "Metallizing," a publication of Metalweld, Inc., are available on request from the company, 26th and Hunting Park Ave., Philadelphia 29, Pa.

Controlling Interest of the Leader Iron Works Co., 2100 N. Jasper St., Decatur, Ill., has been bought by Julius H. Peters, formerly with Colonial Iron Works, Cleveland. The firm manufactures steel and alloy chemical processing equipment and storage tanks.

Ultraviolet Light examination of materials is possible with a portable device combining a light source at either 2537 or 3660 Angstroms and an eyepiece providing 3X magnification. The 2-lb. device is made by Menlo Research Laboratory, P. O. Box 522 CY, Menlo Park, Cal.

Catalog 94 of Fischer & Porter Co., Hatboro, Pa., describes glass pipe and fittings for laboratory, pilot plant and special services.

Bitucote Protective Coating, a bulletin of Bitucote Products Division of Bridges Paving Co., 1411 Central Industrial Drive, St. Louis 10, Mo., describes the characteristics, use and applications of its emulsified asphalt products.

Nu-Kast No. 166 Pump, a product of Nukem Products Corp., Buffalo 20, N. Y., is designed to pump liquid corrosives and Nukemizing, a process for applying a flame-sprayed membrane for corrosion-proofing tanks handling corrosives are described in two recent bulletins.

A Dry Coating resistant to salt spray and high-humidity exposures is possible through use of a wax developed by S. C. Johnson & Son, Inc. Protection to aluminum, steel, brass and other metals is claimed after tests including more than 300 hours in a 20 percent salt spray. Adequate protection to steel after five weeks outdoors in winter also is claimed.

"Carlon" Plastic Pipe, for transportation of many types of corrosives and tubing for processing applications are described in several folders and sheets issued by The Carter Products Co., Cleveland 5, Ohio. Corrosives to which the material is and is not satisfactorily resistant are listed.

"Rustchrome," Chromium chromate in solution in an oil menstruum penetrates through rust to the metal surface and deposits a stable film of chromium, the manufacturers say. Further information

can be obtained about this and Zinkromex, a zinc chromate rust inhibitor and metal primer, Nuprimex, a masonry waterproofing, Phenolex and Leadlex, other products of Claronex Products, Inc., 239 Java St., Brooklyn, N. Y.

Rubber Lining of tanks under its exclusive "Laybond" process is done by Acme-Fisher of Texas, 7700 Wallisville Road, Houston. The 10,000-square-foot plant can reline or repair rubber linings in large and small tanks. Personnel consists principally of experienced lining applicators from the Louisville plant of the company.

Apex Smelting Co. has issued a folder-type brochure giving principal facts about the use of Apex magnesium anodes for cathodic protection. Copies may be obtained from the firm's offices, 2537 West Taylor St., Chicago 12, Ill.

Karbate Pipe Threads now can be cut with a new hand threader details about which may be secured from National Carbon Division, Union Carbide and Carbon Corp., 30 East 42nd St., New York 17, N. Y. A new catalog section illustrates Series 240A Karbate impervious graphite shell and tube heat exchangers. Those interested should ask for Catalog Section M-8801.1.

An Aluminum pipe jacketing available with or without a glued-on asphaltic moisture barrier that can be used over any moulded insulation with the moisture barrier is made by Childers Manufacturing Co., 625 Yale Street, Houston, Texas.

A Long List of corrosion resistant products made by Sharon Steel Corporation, Sharon, Pa., is in a current 4-page folder which also gives engineering characteristics of materials and shows some uses for specific products.

Thelco constant temperature cabinets for routine laboratory jobs are illustrated and described in a brochure available from Precision Scientific Co., 3737 West Cortland, Chicago 47, Ill.

Dekoron Tubing, an instrument tubing made of metal with a 1/32-inch coating of extruded thermoplastic, is a product of Samuel Moore & Company. It is useful in corrosive environments because it resists moisture, salt, oils, acids and alkalies and can be bent readily. Further information and sample lengths may be had from the company's Mantua, Ohio, offices.

Galv-Weld, a low melting point zinc base alloy used to re-coat welded areas with a corrosion-resistant layer of metal now is available through sales offices of United States Steel Supply Company.

Plastic Stud and bolt protection manufactured by F. H. Maloney Co., Houston 1, Texas, is described in a 4-page brochure titled "Maloney Plastic Stud and Bolt Protection."

Ensign Vibrust, a tar containing as filler only long fibre asbestos, has high resistance to marine environments, is sound deadening, has high dielectric strength, does not carry a red or yellow label and may be applied by brush or air gun. Full information may be secured from Ensign Products Co., 3528 East 76th St., Cleveland 5, Ohio.

All-Monel pressure snubbers have been added to its line of stainless steel and brass snubbers by Chemiquip Company, 193 Bradford St., Brooklyn 7, N. Y., for use where this alloy is especially resistant to corrosion. They are designed to protect pressure gauges and other pressure instruments from shock resulting from sudden pressure development or release. The snubbers also act as filters for liquid or air lines under some conditions.

Foster & Kester, Co., Inc., 2601 North Broad St., Philadelphia 32, Pa., has changed its name to Krylon, Inc.

Westcoat-Clear, an ethylcellulose strippable coating is useful in protecting metals from corrosion and abrasion. Applied as a hot melt (325-350 degrees F) the air-dried material is highly resistant to moisture penetration. Manufacturers, Western Coating Co., 85 West Union St., Pasadena 1, Cal., will supply additional information on request.

End-O-Rust, a corrosion and oxidation resistant coating has high resistance to many corrosives, according to the manufacturers, End-O-Rust, Inc., 1900 Euclid Ave., Cleveland, Ohio.

Selenium is an element in a metal primer, R-10-X, a proprietary compound manufactured by Thompson-Long Co., Board of Trade Bldg., Chicago 4, Ill. Manufacturers say the selenium combines with ferric oxide by chemical action.

• **La**

2.3

Pain ner. *Co* May.—

2.3, 4.3
A C Use in Halls 2136 (

Exp comme types charter

2.3, 5.4
The of Ant son wi Chamb *Iva,* 19 No. 10

Stee of asph lead an ore an a grou paint a Vila a results water The s best th its us some The consum rapid

Corrosion Abstracts

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

TESTING

• Laboratory Tests

2.3

Paint Testing Laboratory. P. A. Gardner. *Can. Pt. and Varnish*, **22**, 38+ (1948) May.—BL.

2.3, 4.3, 6.7

A Comparison of Some Metals for Use in Acid Pickling Baskets. E. E. Halls. *Sheet Metal Ind.*, **26**, 2127-2130, 2136 (1949) Oct.

Experimental results for a series of common metals and alloys in several types of pickling solutions are tabulated, chartered, and discussed.—BLR.

2.3, 5.4

The Vila Method for Rapid Testing of Anti-Rust Paints on Steel. Comparison with Salt-Water Spray and Tropical Chamber Tests. S. Kohler & K. Laurell. *Iva*, 19, 234-48 (1948); *Chem. Abs.*, **43**, No. 10, 4023d (1949).

Steel panels painted with: a) 2 coats of asphalt vsh., b) a ground coat of red lead and a second coat of micaceous iron ore and aluminum powder paint, or c) a ground coat of red lead and a plastic paint as second coat, were tested in the Vila app. (Review, 1936, 137₆) and the results compared with those of salt-water spray and tropical chamber tests. The salt-water spray test reproduces best the conditions of practice, so that its use is recommended, at least in some cases, in place of the Vila test. The tropical-chamber test is too time-consuming and therefore not suitable for rapid testing.—RPI.

2.3

Accelerated Test for Evaluating the Protective Power of Finishes. A. J. Arker & W. R. Frisch. *Org. Fin.*, 9, No. 5, 9-19 (1948); *Chem. Abs.*, 42, No. 20, 7996b (1948).

A corrosion test involving exposure of ⅛-inch steel panels to vapor containing SO₂ is described. The gain in weight due to corrosion products is measured.—RPI.

2.3, 3.6

A Note on the Effect of Variations of Exposed Area on the Solution Potential and Corrosion Rate of Low Carbon Steel. J. M. Bialosky. *Corrosion*, 5, 346-349; discussion, p. 349 (1949) Oct.

Solution potential and weight losses were measured. Tests were conducted in a circular path apparatus with aerated 3.5 percent salt solution as the corroding medium. The concentration of the corroding solution, temperature, aeration, solution volume, and velocity were controlled. Data are tabulated and plotted.—BLR.

2.3, 5.4

Electrical Method for Evaluation of Protective Coatings as Moisture Barriers. Marion A. Arthur. *ASTM Bull.*, 57-58 (1949) Sept.

Tests of waterproofing materials for various electrical parts were completed in a matter of weeks by measuring resistance changes of coated insulators during immersion cycles. Typical data are tabulated. 17 ref.—BLR.

2.3, 1.7, 6.3

Standard (ASTM) Method of Mercurous Nitrate Test for Copper and Copper Alloys. (B154-45.) (ASTM Standards on Copper and Copper Alloys, **1948**, 316-318).—MA.

2.3

Radioactivity to Control Rust. C. G. Bacon. *Blast Furnace & Steel Plant*, **37**, No. 10, 1225 (1949) Oct.

By using radioactive tracers, a method was developed which revealed photographically how rust starts, where it starts and how deep it goes. In experiments a solution holding radioactive iron is electroplated onto surface of the metals to be studied. A photographic plate is placed against the surface and left for several days. As the test metals rust, a decrease in radiation results, showing up graphically as lighter areas on photographic plate.—INCO.

2.3, 6.2

A Method for Activating Stainless Steel Specimens Prior to Corrosion Tests. R. O. Bayer and E. A. Kachik. *Corrosion*, 5, 308-310 (1949) Sept.

In corrosion testing the austenitic stainless steels, it often happens that some of a group of apparently identical specimens, under the same conditions, will corrode while others will not. This behavior is termed borderline passivity. Describes procedure for ensuring that all specimens are initially active. This

involves pickling just prior to introduction into the corrosive medium. Typical data are tabulated.

2.3, 3.3, 5.4, 7.7

Effect of Soil Microorganisms on Rubber Insulation. John T. Blake and Donald W. Kitchin. *Ind. and Eng. Chem.*, 41, 1633-1641 (1949) Aug.

Presents evidence showing that some of the rare failures of nonleaded rubber insulated underground cables were caused by soil microorganisms. Laboratory conditions made possible accelerated tests in which failures like those found after 10 years or more in service were produced in a few weeks or months. 28 ref.—BLR.

2.3

Solutions for Maintaining Constant Relative Humidity. D. S. Carr and B. L. Harris. *Ind. & Eng. Chem.*, 41, No. 9, 2014-2015 (1949) Sept.

Measurement of the vapor pressure and relative humidity of 12 saturated salt solutions at temperatures from 15-90°C.

2.3, 4.4, 8.9

The Corrosive Sulphur Test. G. Claxton and K. H. V. French. *J. of the Inst. of Petro.*, 35, 496-507 (1949) July.

Describes addition to the copper-strip test by which it is possible to study the corrosion of copper by motor fuels on a more quantitative basis than previously. This addition depends upon conversion of the sulfide stain on the strip into H₂S, which is estimated colorimetrically. The mutual activation of corrosion by H₂S and elementary sulfur was studied quantitatively. The inhibitor most commonly present in motor gasoline appears to be a peroxide of either cyclopentadiene or its dimer. The quantity necessary to cause inhibition is extremely small and cannot be detected by the starch-iodide reaction. 13 ref.—BLR.

• Instrumentation

2.4, 5.4

High Speed Aircraft Paint Adhesion Testing Device. G. W. Grupp. *Organic Fin.*, 9, 9-11 (1948) Dec.—BL.

2.4

Stereoscopic Radiography. F. Hargreaves. *Engineer*, 188, 154-155 (1949) Aug. 5.

Describes and illustrates above technique as applied to welding in locomotive construction and repair.—BLR.

2.4, 8.9

Ultrasonic Testing of Aircraft Components. W. C. Hitt. *Iron Age*, 163, No. 25, 66-70 (1949) June 23.

Ultrasonic equipment is used to measure thickness of aircraft parts when only one side of part is accessible, and to locate subsurface defects. Present paper describes the Sonizon, an instrument made by Magnaflux Corp., Chicago, on which thicknesses of 0.015-0.500 in. can

PRIMARY SOURCES OF ABSTRACTS PUBLISHED IN CORROSION

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 500 5th Ave., New York 18, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

ME—Marine Engineering, The Institute of Marine Engineers, 85/88 The Minories, London E. C. 3, England.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

---

be read directly with a working accuracy of 2%.—BNF.

2.4
Supersonic Vibrator to Detect and Locate Flaws in Materials. Sperry Products Inc. *Ind. Equip. News*, **16**, 1 (1948) July.—BL.

2.4
Non-Destructive Material Testing. Rudolph Lindemann. *Technik*, **4**, No. 4, 151-160 (1949).
The various non-destructive methods of material testing such as magnetic, X-ray, X-ray metallographic, Y-ray, ultrasonic, etc., and their potential use are discussed. Some examples are shown in diagrams and micrographs.—MA.

2.4
Round Table Discussion on Ultrasonic Testing. ASTM, 23 pages.
Presents transcript of above discussion, held at the 51st annual meeting of the ASTM, Detroit, June 21, 1948.—BLR.

2.4, 7.2, 7.7
Corrosion Tester. *Can. Metals & Met. Inds.*, **12**, No. 10, 26 (1949) Oct.
A new portable potentiometer, designed for corrosion steel work, makes possible fast, accurate, dependable readings over a wide range encountered when investigating galvanic and electrolytic action along pipe lines, cables and other varied metal structures. Mfd. by Leeds & Northrup Co.—INCO.

CORROSION TYPES & INFLUENCING FACTORS

• Types

3.2, 3.5, 7.2
Corrosion Fatigue Cracking in Steam Pipes. Corrosion Fatigue Committee Appointed in 1937 by the Central Electricity Board. Published by British Electricity Authority, Great Portland St., London, W. 1. *Eng.*, **1949**, No. 198, 330, Sept. 16.
Describes mechanism of crack devel-

opment, the locations at which failure may be expected, methods of detection and observation.—INCO.

3.2, 3.5, 6.3
High Temperature Scaling of Cobalt. Charley R. Johns and William Marsh Baldwin, Jr. *J. of Metals* (Technical Section), **1**, 720-721 (1949) Oct.
Reviews previous work and reports results of an investigation on the discrepancies observed. 11 ref.—BLR.

3.2, 3.4, 1.8
The Mechanism of Cracking in the Stress-Corrosion of Homogeneous Alloys. I. The Cause of Inter- and Intercrystalline Cracks. (In German.) Ludwig Graf. *Zeitschrift fur Metallkunde*, **40**, 275-280 (1949) July.
Research on silver-gold and copper-gold alloys shows that the type of cracking depends mainly on the nature of stress-producing agent and that intracrystalline cracks can be caused only by highly oxidizing agents, while intercrystalline cracks are caused by weak oxidizing agents. Presents X-ray diagrams and tabulated data. 18 ref.—BLR.

• Factors Biological

3.3, 5.4
Interpretation of Fouling Samples From Ships. M. W. H. Bishop, K. A. Pyefinch & M. F. Spooner. *J. Iron & Steel Inst.*, **161**, Pt. I, 35-40 (1949); *J. Brit. Shipbuilding R. A.*, **4**, No. 3, 157 (1949).
The authors consider the results that can be obtained from a set of samples of the fouling of a ship and the deductions than can be drawn.—RRI.

3.3, 6.5
Finding and Fighting Marine Borers. R. D. Chellis. *Eng. News-Record*, **140**, 344-7 (1948) Apr. 555-8; *Prev. Det. Abs.*, **1949**, 6, B 16-8.
Borers causing most damage to ocean timber are indicated. The conditions which effect their growth and several methods for protecting wood from them are given.—RPI.

• Factors Chemical

3.4, 1.8
Investigation of the Corrosion of Iron in Contact with Solutions of Electrolytes and Organic Liquids. The Influence on the Corrosion Process of Various Anions and Cations. (In Russian.) I. V. Krotov. *Akad. Nauk, USSR, Doklady*, **59**, No. 8, 1453-1456 (1948).—BL.

• Factors Physical and Mechanical

3.5, 7.1
Cavitation of Screw Propellers. R. W. L. Gown. *Trans. N. E. Coast Instn. Eng. and Shipbuilders*, **65**, 339-374 (1949) Apr.
Cavitation Characteristics are deduced from ship trials and model experiments. There is a limit to present extent to which cavitation tests simulate ship conditions, but important advances are made. This is confirmed by examples for two-bladed propeller, five-bladed propeller and erosion. Appendix II describes model propeller production in manganese bronze.—INCO.

3.5, 6.2
Effects of Hydrogen in the Corrosion of Steel. *Iron Age*, **162**, 78 (1948) July 29.—BL.

• Factors Electrochemical

3.6, 8.4
Notes on Galvanic Corrosion. F. L. LaQue and W D. Mogerman. *World Oil*, **129**, 153-154+ (1949) Oct.
Develops the theory of bi-metallic corrosion, and shows the relative intensity of corrosion of metals placed in conditions of electrolytic action. Includes recommendations as to choice of metals with emphasis on one-metal construction wherever possible.

• Factors Metallurgical

3.7, 1.8
Surface Problems in the Chemical Behavior of Metallic Materials. (In German.) W. Guertler. *Metalloberflache*, **3**, Sec. A, A133-A141 (1949) July.
Contrasts the behavior of single crystals of metals with that of multi-crystalline aggregates encountered in practice. Points out importance of the surface in relation to the space lattice and differentials between adherent and non-adherent corrosion products. Shows that the corrosive behavior of alloys is determined by microscopic and submicroscopic structural factors. The basic prerequisites for producing chemically resistant alloys are discussed in detail. Includes lattice diagrams.—BLR.

3.7
The Relationship Between Adsorbing Capacity (of Powder Metallurgy Products) and Corrosion. (In German.) G. F. Huttig. *Berg- u. Huttenm. Monatsh, Leoben*, **94**, Nos. 8/9, 282-284 (1949) Aug./Sept.—BNF.

ENVIRONMENTS

• Chemicals Inorganic

4.3, 6.7

Corrosion of Metals in Red Fuming Nitric Acid and in Mixed Acid. N. Kaplan and R. J. Andrus. *Ind. & Eng. Chem.,* **40**, 1946-1947 (1948) Oct.—BL.

4.3, 6.7

Sulphuric Acid Versus Construction Materials—I & II. Corrosion Forum. *Chem. Eng.,* **55**, No. 5, 235-236+; No. 6, 223-224+ (1948) May, June. Symposium includes:

Rubber Linings by O. S. True (U.S. Rubber Co.)

Cast Iron and Steel by A. W. Spitz (Amer. Cyanamid Co.)

Worthite by E. T. Collingsworth (Worthington Pump & Mach. Corp.)

Hastelloy, by C. G. Chisholm (Haynes Stellite Co.)

Stainless Steel by W. G. Renshaw (Allegheny-Ludlum Steel Corp.)

Precious Metals by E. F. Rosenblatt (Baker & Co.)

Durimet by W. A. Luce (Duriron Co.)

Carbon, Graphite by W. W. Palmquist (Nat. Carbon Co.)—INCO.

4.3, 6.7, 6.5, 5.4

Corrosion Forum-Hydrofluoric Acid versus Construction Materials. *Chem. Eng.,* **56**, No. 8, 233-334; No. 9, 229-230; No. 10, 227-228+ (1949) Aug., Sept., Oct.

Symposium includes:

Carbon and Graphite by J. F. Revilock (National Carbon Co.)

Chlorimets by W. A. Luce (Duriron Co.)

High Silicon Irons by W. A. Luce.

Stainless Steel by W. G. Renshaw (Allegheny Ludlum Steel Corp.)

Hastelloy Alloys by C. G. Chisholm (Haynes Stellite Co.)

Iron and Steel by A. W. Spitz (American Cyanamid Co.)

Lead by K. H. Roll.

Silicones by J. A. McHard & A. F. Kolb (Dow Corning)

Nickel, Nickel Alloys by W. Z. Friend (Inco)

Durimet-20 by W. A. Luce.

Rubber-Lined by E. L. Lockman (U. S. Rubber Co.)

Protective Coatings by K. Tator.

Materials not recommended are chemical stoneware, tantalum, glass-lined steel and aluminum.—INCO.

• Soil

4.5, 6.5, 2.2, 5.2

Chemical Aspects of Underground Corrosion and Corrosion Prevention. I. A. Denison. *AGA Proc.,* **30**, 517-33 (1948).

The first part of this article deals with the underground corrosion of ferrous metals, and includes sections on pitting and the effect of the chemical constitution of the soil and the alloy composition of the metal on corrosion. The section devoted to the corrosion of zinc and galvanized materials contains results of a 10-year underground exposure test. It was found that in several of the soils the losses in weight of the galvanized specimens were much less than those for either the zinc or the steel specimens; this result, it is suggested, must be an effect of iron-zinc alloy layers. Corrosion of copper, brass and lead is also discussed. Zinc anodes for cathodic protection gave good results in most soils, and it is suggested that the use of high grade zinc is advantageous. The use of aluminum and magnesium anodes for this purpose is dependent on the proper choice of alloy and chemical backfill.—ZDA.

4.5, 4.6, 7.2, 7.7

The Inhibition of Corrosion. W. F. Gerrard. Ministry of Fuel and Power: *Fuel and the Future,* **2**, 254-263 (1948); discussion, 263-265.

A general survey, in which water treatment and the prevention of the corrosion of underground pipe-lines and cables are considered. 21 references are given.—MA.

• Water and Steam

4.6, 7.2, 7.4, 2.2

Boiler Maintenance—Feed Water Treatment. L. F. Collins, Detroit Edison Co. Paper before AISE District Section Mtg., Apr. 12, 1949. *Iron & Steel Eng.,* **26**, No. 9, 70-72 (1949) Sept.

In the field of municipal water supplies it has been estimated that the "extra" pumping costs resulting from roughing of the inner surface by corrosive attack amounts to about 10% of the gross revenue of the average water utility. Formula is given for determining maintenance labor required to descale heat transfer equipment. Investigations in the electrical utility field attest that the cost of tolerable amounts of slime in condensers is of the order of $50 to $70 per year per 1000 KW of capacity. By means of corrosion tester, which is diagramed, one can determine in 30 days or less the rate at which any selected metal will be attacked by the contacting medium under actual operating conditions. Slime and scale prevention and degasification are discussed.—INCO.

4.6, 3.4, 6.7

Behavior of Metallic Materials Towards Very Dilute Aqueous Solutions. (In German). L. W. Haase. *Archiv Metallkunde,* **1**, No. 6, 259-264 (1947) June; **3**, No. 3, 96-99 (1949) March.

Relation between chemistry of water and corrosion; solubility of iron in aqueous salt solutions; formation of protective layer and metallic hydroxides; behavior of lead, zinc, galvanized iron, aluminum and iron in natural waters; corrosion of metals by water, soils and moisture. Appearance of specimens; effect of alklinity at metal surfaces and structure of the corrosion products on primary metal attack; special behavior of tin and aluminum towards alkilis, fats and fat-containing water.—BNF.

4.6, 3.4, 6.7

The Resistance of Metallic Materials to Very Dilute Aqueous Solutions. II. L. W. Haase. *Arch. Metallkunde,* **3**, No. 3, 96-99 (1949). *Cf. Met. Abs.,* **15**, 509 (1948).

It is known that, in very dilute solutions, the corrosion of metals, including the so-called noble metals, depends to a great extent, if not completely, on the chemical properties and structures of the oxidation products. With all metals whose normal potentials are lower than that of hydrogen, an increase in oxygen concentration causes an increase (nonproportional) in the rate of corrosion. The structure of the corrosion products is influenced by their rate of formation and determines whether attack continues or ceases. Continuance of corrosion is related to: a) alkali formation at the metal surface, and is, therefore, proportional to the oxygen concentration at such surfaces, and b) the chemical properties of the corrosion products towards alkalies.—MA.

4.6, 8.1

Water Treatment for Heating and Air Conditioning. W. H. Lang. *Heating & Vent.* **45**, 98-112 (1948) Oct. References.—BL.

PREVENTIVE MEASURES

• Cathodic Protection

5.2, 7.7

Install 25 Ground Plates to Cathodically Protect Cable. L. F. Greve. *Elec. World*, **130**, 112, 116 (1948) Sept. 11. —BL.

5.2, 4.6, 7.10

The Cathodic Protection of Steel Piling in Sea Water. H. A. Humble. *Corrosion*, **5**, No. 9, 292-302 (1949) Sept.

The corrosion rate of alternately immersed uncoupled steel specimens in sea water was shown to be very high and to increase with increasing time of exposure to the atmosphere. Authors conclude from a number of experiments on small specimens in the sea at Kure Beach that the best method of protecting steel piling in sea water is the use of Monel sheathing above mean low tide level in addition to cathodic protection.—BNF.

5.2, 6.7

Corrosion Prevention. F. L. LaQue. *Can. Metals Met. Inds.*, **12**, No. 8, 14-7+ (1949) Aug. *Corrosion*, **6**, 72-78 (1950) Feb.

This article is devoted to methods of preventing corrosion, other than by the use of protective coatings. One such method is that of cathodic protection using zinc or other anodes, in which zinc is allowed to corrode and so generate a current inhibiting corrosion of such articles as bronze propellers, copper boiler tubes, etc. The effects of design and composition of materials on their rate of corrosion are also considered.—ZDA.

5.2

Electrochemical Principles of Cathodic Protection. R. H. Brown and G. C. English. Cathodic Protection Symposium (Electrochemical Society and National Association of Corrosion Engineers), 1947 (published 1949), pp. 7-11.

The theory of cathodic protection developed from the local cell picture of electrochemical corrosion.—BNF.

5.2, 8.9, 7.2

Mitigation of Corrosion of Bare Pipe Lines by Application of Magnesium Anodes. R. L. Bullock. *Oil & Gas J.*, **48** No. 22, 267-268, + (1949) Oct. 6.

Steps in maintaining old bare pipe lines consists of: 1) installation of magnesium anodes at location of all leaks that had occurred since 1935, 2) installation of magnesium anodes on all new leaks as they occur and 3) discontinuance of extensive permanent repairs on serviceable trunk pipelines.—INCO.

5.2, 7.2, 8.9

Engineering Aspects of Cathodic Protection as Applied to Pipe Lines. E. P. Doremus, G. L. Doremus and M. E. Parker, Jr. *Corrosion*, **5**, No. 9, 273-281 (1949) Sept.

Discusses the problem of designing a system to provide complete cathodic protection, i.e., one which will prevent current from leaving the line at any other than the preselected drainage points; costs are also considered.—BNF.

5.2

Ribbon Anode Developed for Cathodic Protection. Dow Chemical Co. *Elec. World*, **131**, 82 (1949) May 7.—BL.

Abstract Section Style Outlined

For ease in locating reference data, CORROSION uses a uniform style in its Abstract Section.

The abstracts first are broken down into major classifications of the more common types of corrosion literature. In each review the title of the article is presented in bold face type, followed by the author's name. The publication from which the article was abstracted is printed in italics and is abbreviated in most instances. Following this, in sequence, are the volume (bold face), number in the volume, pages, year and month of publication. In some instances a second reference will be listed in the same manner. This indicates that the article also was published or abstracted in another publication. A brief summary of the article follows the above information and it is concluded with an abbreviation indicating the source of the abstract and contributor. The meanings of these abbreviations usually are listed on the first page of the Abstract Section.

When seeking more detailed data about an abstract, best source of information is the publication in which the article appeared originally. (Listed in italics in the heading.) The contributor of the abstract also may be able to supply additional information. Addresses of most of these publications may be found in the reference section of most public libraries.

• Metallic Coatings

5.3, 7.0, 6.2

Protective Coatings for Steel. *American Machinist*, **93**, No. 18, 143, (1949) Sept. 8.

A solid solution of aluminum and iron, in which the outer layer is rich in aluminum and the inner layer rich in iron, has been developed to protect steel from oxidation and scaling at elevated temperatures. The treatment is as follows: 1) pack articles in drum in a mixture of powdered aluminum oxide and ammonium chloride (1 to 5%); 2) rotate drum slowly while being heated (for about 5 hours at 1740° F-949° C) and maintain a reducing atmosphere, usually of hydrogen, within it.

The aluminum content employed in the process may vary from 5 to 50% according to the service to which the treated piece is to be put. Calorizing temperatures of 850 to 950° C (1562-1742° F) are recommended for iron and steel, and 200 to 800° C (392-1472° F) are recommended for copper and brass. The purpose of the alumina is to prevent coalescence of aluminum particles as the temperature used is higher than the melting point of aluminum (660.2° C, 1220° F). The aluminum and the chloride must be renewed from time to time as the mixture is used.

The calorizing process may be carried out by using steel previously coated with aluminum by the hot-dip process. Upon heating, the aluminum diffuses into the underlying metal, producing a coating similar to that obtained by calorizing, but thinner and less protective. Oil refining equipment, valves, retorts, condenser parts, stokers, roasters, rotary kilns, carburizing and heat-treated boxes, pyrometer protection tubes and burner nozzles may be calorized advantageously.—ALL.

5.3

Hot Galvanizing Practice. A. T. Baldwin. *Steel*, **22**, 86+, (1948) May 31.—BL.

5.3, 5.9, 6.4

Inorganic Finishes for Light Metals. Jerome L. Bleiweis. *Prod. Eng.*, **20**, 114-118 (1949) Sept.

Considers cost, availability, and theoretical factors in the selection of the above, which include electroplated metallic coatings, and oxide or chemical conversion coatings. Discusses chemical treatments for optimum corrosion protection. Illustrated.—BLR.

5.3, 2.2, 2.3, 4.2, 1.7

The Institute's New Corrosion Research Stations. *Tin & Its Uses*, **1948**, No. 19, 6 Mar.

When tin and tin alloy coatings and use of tin coatings on steel preparatory to painting was studied, accelerated tests of salt-spray, humidity and artificial cyclic weathering was supplemented by outdoor exposure tests. Marine and industrial environments were studied. Photographs are included of the four outdoor exposure racks.—INCO.

5.3

Increase of Corrosion-Resistance by Protective Coatings on Zinc and Its Alloys, Obtained by Chromium Plating. (In Russian) A. V. Turkovskaya and G. S. Reveko. *Vestn. Inzhen. Tekhn.*, **1948**, 67-68 (Mar./Apr.)—MA.

5.3

Diffusion of Zinc in Metals (Aluminum) and Light Alloys. J. Grillat. Groupement Franc. Develop. recherches aeronaut. Note tech. 58, 19 pp. (1946); *Chem. Abs.* (USA) **43**, 534 (1949) Jan. 25.

A series of experiments were carried out on the protection afforded to aluminum, duralumin and duralinox by zinc coatings applied by electrodeposition, spraying, immersion in a bath of molten zinc and heating in powdered zinc. The conclusion reached was that below the zinc-aluminum eutectic temperature (380° C) diffusion of zinc into aluminum is very slow, judging from examination of photomicrographs of several of the zinc-aluminum interfaces.—ZDA.

5.3, 7.6, 7.4

Galvanizing. Wilhelm Haarmann. *Metalloberflache*, **3**, No. 2, 43-44 (1949).

A review, with special reference to the procedure necessary for the successful production of coatings on the internal surfaces of boilers, overflow tanks, straight and coiled tubes, and other hollow articles.—MA.

5.3, 8.7

Concerning Different Gold-Plating Methods. (In German.) Otto Loebich. *Metalloberflache*, **1**, sec. B, B55-B-57 (1949) July.

Discusses methods of gold-plating for ornamental color effect and for protection against corrosion.—BLR.

5.3, 8.9

Electrogalvanizing—An Example of Spray-Zinc Coating of Large Iron Structures. (In Swedish.) Bo Lofgren. *Finish* (Sweden), **6**, 49-51 (1949) Mar.

Describes the above as a method of protecting steel ship hulls, etc., from corrosion. Illustrated.—BLR.

After...
types...
gives...
ment...
merit...
listed...
of pr...
finish...
acter...
plicat...
other...
ing f...

5.4

Pla
Proc...
Pipel...
9, 10...

Pla
of h...
and i...
Thic...
of at...
the s...
deter...
flow...
stand...
INC...

5.4

Cl
Fin.,
43, N...

Fi
store...
shou...
lacqu...
few...
caus...
solve...
warn...
nigh...
out...
prec...
enar...
lutio...
to s...
is u...
not...
mate...
teric...
corr...
shou...
finis...

5.4,

St
tions...
ing...
the S...
Com...
allum...
Com...
Steel...
June...
337...

F
stag...
foul...
oxid...
are...
tion...
for...
prou...
with...
used...
can...
avai...
age...
able...
initi...

• Non-Metallic Coatings

5.4

How to Specify Organic Finishes. A. L. Alexander. *Prod. Eng.* (USA). **20,** No. 7, 141-5 (1949) July.

After briefly describing the various types of organic finishes, the author gives a list of corrosion inhibiting pigments without mentioning their relative merits. Several types of resin are next listed and are followed by a discussion of production requirements for organic finishes. One table indicating the characteristic properties and suggested applications of various vehicles, and another listing six typical industrial finishing formulations, are given.—ZDA.

5.4

Plastic Pipe Line Coating and Yard Processing. B. M. Laulhere, Pacific Pipeline & Eng., Ltd. *Pet. Eng.,* **19,** No. 9, 104-106 (1948) June.

Plastic material is fed into a stream of hot air, is brought to fusion point and is then blown on pipe to be coated. Thickness is controlled by temperature of air, and is uniform. Samples under the salt-crock test do not show signs of deterioration or lowered resistance to flow of current. Coating is tough and stands abrasion and rough usage well.—INCO.

5.4

Clean Finishes. R. H. Wampler. *Org. Fin.,* **9,** No. 9, 25-8,36 (1948). *Chem. Abs.,* **43,** No. 3, 1197h (1949).

Finishing materials should not be stored in a heated atm. and old stock should not be utilized. Drums of flat lacquer stored in hot sunlight may in a few days develop a coarse graininess because the flatting agent partly dissolves in the lacquer while it is quite warm and, when the material cools at night, the dissolved material precipitates out as coarse lumps. Extreme cold can precipitate materials in varnishes and enamels which do not go back into solution at room temp. It is a good policy to strain or filter every material as it is used. The pigments in enamels may not be perfectly broken up when the material is stirred and reduced. The interiors of drums may corrode and the corrosion products may break loose and show up as hard, black specks in the finish.—RPI.

5.4, 3.3, 4.6

Studies on Anti-Fouling Compositions—Pt. VI—The Leaching Rate During the Early Stages and Its Relation to the Surface Conditions in Cuprous Oxide Compositions. H. Barnes. BISRA, Metallurgy Div., Marine Corrosion Sub-Comm., Paper MG/BC/3/49. *J. Iron Steel Inst.,* **162,** Pt. 2, 179-185 (1949) June. *J. Brit Shipbuilding R.A.* **4,** No. 7, 337 (1949).

Factors governing the initial and later stages of the leaching process of anti-fouling compositions containing cuprous oxide are different, and the initial stages are considered separately. Dilute solutions of citric acid in sea water are used for studying available particulate cuprous oxide, since this reagent is almost without action on the varnish media used. Copper extracted by this reagent can be used to estimate the surface-available cuprous oxide. Use of this reagent indicates that the surface-available cuprous oxide is responsible for initial leaching rate of the compositions.

It is pointed out that it is difficult to generalize from the results obtained regarding the effect of various components of the compositions on this surface-available cuprous oxide, since the conditions were not adequately controlled. Overlying the uniform portion of the paint film, a layer of almost pigment-free varnish may be formed and the relation of this to early leaching rates is considered. Some practical considerations with regard to varnish-film formation and its prevention are noted. 3 refs. See also *T. Iron & Steel Inst.* **161,** Pt. 2, 98-9 (1948).—INCO.

5.4, 4.5, 7.2

Modern Protection Methods for Cast-Iron and Steel Pipes, and the Experience Gained With These Methods in the Netherlands. J. E. Carriere. (Paper, 4th International Gas Conf., London (6/15-17/49); abstr. *Engineering,* **168,** No. 4353, 17 (1949) Jl. 1.

Systematic coating of pipes with asphalt bitumen of the blown type was used to combat corrosion in parts of the Netherlands where the life of cast-iron and steel pipes laid in strongly corrosive soils was as little as five or six years. Regulations relative to the various thicknesses of asphalt which must be applied for varying degrees of protection are briefly outlined.

5.4

Prime Coatings—An Investigation and Evaluation. *Can. Pt. & Varnish,* **22,** 16+ (1948) Sept.—BL.

5.4, 2.3

Organic Coatings in Theory and Practice. A. V. Blom. 298 Pages. 1949. Elsevier Publishing Co., New York.

Presents fundamentals of organic coatings. Describes natural and synthetic film-forming materials, physical film formation by evaporation or congelation, different types of chemical film formation, characteristics of pigments, film properties, and testing methods. Includes tables, graphs, illustrations, and footnote references.—BLR.

5.4, 5.9

Corrosion-Protecting Paints for Submerged Metal Structures. A. V. Blom. *Peint. Pig. Vernis,* **25,** No. 1, 10-15 (1949).

The causes of corrosion of steel are reviewed, and pre-treatments before painting and painting treatments discussed. Removal of mill scale is difficult but it is suggested that flame descaling is one of the best methods of effecting it. Paints which tend to swell, e.g., linseed oil paints, or are water-permeable, should be avoided. Bituminous and chlorinated rubber paints are suitable for industrial application. The possibilities of water-resistant resins applied without solvents and polymerized in situ are discussed.—RRI.
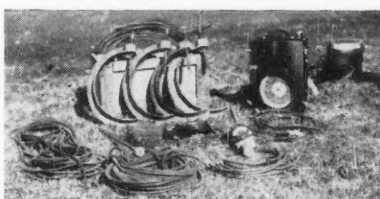
5.4

Hot Melt Coating. *Chem. Eng.* **56,** No. 8, 168, 170 (1949) Aug.

Westcoat Clear is a strippable protective coating that prevents rust, corrosion and abrasion. Salt water and salt air have no effect upon parts treated with it. Coated parts can withstand temperatures ranging from 40-160° F. In use, compound is heated in a tank to about 350° F to melt. Metal part is dipped about 10 minutes and allowed to air-dry. When need for protection is past, the coating is removed by slitting it with a knife and pulling it off in one piece. Mfd. by Western Coating Co.—INCO.

5.4, 2.3, 1.7

Some Aspects of the Weathering of Paint Films. G. A. Christie. *South African Industrial Chemist,* **3,** No. 4, 62-4 (1949).

A discussion of the factors affecting the breakdown of paint films, including references to American investigations and accelerated weathering app. The author's experience is that the test cycle described in ASTM D. 822-45T gives good results. A plea is made for cooperative work in S. Africa along USA lines.—RPI.

5.4, 1.2

Annual Rust and Corrosion Loss.
Rogers Clark. *Sheet Metal Worker*, 40,
40-41, 43 (1949) Sept.

Describes the development of fish oil
as a primer coat to prevent corrosion.—
BLR.

5.4, 2.5

**Principles of Writing Specifications
for Metal-Protective Paints.** W. W.
Cranmer, *Corrosion*, 5, No. 7, 234-6
(1949).

The author favors composition specns.
supported by performance clauses as a
means of checking adherence to for-
mula.

5.4, 6.7

**Coating System Protects Metal
Against Corrosion.** *Die Castings*, 7, No.
10, 60 (1949) Oct.

Cyclon series WPS, a new selective
coating system, is for the protection
of all types of metals that are subjected
to extreme corrosive conditions, par-
ticularly, where direct immersion in the
corrosive medium is a necessary appli-
cational factor. Formulated from basic
vinyl resins, it is not affected by acids,
alkalies, their salts, petroleum products,
alcohols, water and many other reagents.
Bond strength is high even with metals
such as zinc, lead, cadmium, aluminum,
nickel, copper stainless steel, galvanized
metals and magnesium. A tie coat and a
final top coat of WPS formulations are
used. When used over the primer it is
recommended for general maintenance
applications where atmospheric corro-
sion is a problem, or where metal pro-
tection is necessary under immersion in
water or mild reagents. Mfd. by Munray
Products, Inc.—INCO.

5.4, 6.5, 2.2

**Outside Exposures of Paint Under-
coats on Wood. Defects After Three
and Four Years.** R. Dooper & F. J.
Hermann. CIMO. Circ., 1949, No. 54,
1-13.

Of the three oil media, those based
on raw linseed oil are now slightly infe-
rior to those based on raw linseed oil
boiled or bodied linseed oil, especially
on the underside of the panels. The me-
dium oil length alkyd is slightly superior
to the short oil. There is no direct rela-
tion between the nature of the pigment
and durability in the oil medium series,
but lithopone tends to give the best re-
sults. Aluminum primers in the alkyd
series, particularly the more highly pig-
mented, are unsatisfactory, showing a
tendency to peel off. Otherwise, varia-
tion of the pigment/medium ratio within
the limits chosen has little influence. All
oil-free primers are unsatisfactory.—RPI.

5.4, 6.5, 2.2

**Exterior Exposure Tests of Wood
Priming Systems.** R. Dooper & H. W.
Talen. CIMO Circ., 1949, No. 57, 8 pp.

Exposures of 2½ years have been car-
ried out on combinations of the systems
primer/knifing filler/finishing coat/and
primer/finishing coat in which each
component was either on an oil or an
alkyd basis (12 in all). In two additional
cases mixed oil/alkyd knifing fillers
were used. The type of primer had no
marked influence on the durability, but
all combinations containing alkyd knif-
ing fillers developed characteristic long
cracks parallel to the grain of the wood.
Complete or even partial substitution of
the ZnO alkyd knifing filler by white
lead/oil eliminated the long cracks.

Other combinations also developed
cracks but these were much shorter. The
use of an oil finishing paint over an
alkyd ground or vice versa led to peel-
ing. In experiments to test the effect of
variations of composition on the per-
formance of alkyd primers, knifing fill-
ers and finishing coats, it was found
that, within the limits chosen, in the
primer the oil length of the alkyd (35
or 23% phthalic anhydride), the nature
of the pigment (I:I white lead/ZnO or
I:Ilithopone ZnO) and the pigment-
medium ratio (55 or 72.5 vol.-%) had
no appreciable influence on the durabil-
ity. The longer oil length alkyd gave
somewhat better results in the knifing
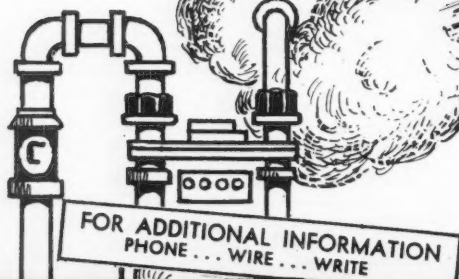filler and considerably better in the fin-
ishing coat.—RPI.

5.4, 2.2, 2.3

Weathering Tests on Paints. W. H.
Droste. *Archiv fur Technisches Messen*,
1948, No. 154; *Elec. Eng. Abs.*, 51, 305
(1948) Dec. *J. Iron & Steel Inst.*, 161, Pt.
3, 266 (1949).

Each type of paint is applied to the
approprite background, e.g., anti-rust
paints to iron, aeroplane paints to light
alloys, wood paints to fir panels, and
house paints to store or mortar. Long-
term weathering tests are carried out
with panels facing south and directed
upwards to an angle of 45°. Laboratory
exposure tests are carried out with: a)
artificial sunlight lamps; b) water, rain,
and steam; c) heating to 50-60° C; d)
cold; e) O_2, and f) corrosive gases for
special paints, e.g., smoke for railway
station paints. Evaluation of test results
is carried out on the DIN "rust scale"
having 5 degrees of severity correspond-
ing to the destruction of 10%, 20%, 30%,
40% and 50% of the painted area. When

degre
sidere

5.4, 6.
Pai
T. D
(1948

5.4
**Bar
in Me**
hoff
Rev.,

K.F.
anti-
metho
finely
650°
diffra
comp
syste
prope
prime
steel,
sidere
sol.
with

5.4
Pri
Orga
W.
(1948

5.4, 2
Zir
Meta
(USA
April

Zir
to re
This
effici
are e
posu
descr

5.4,
A
Pain
W. (
No.

Th
usefu
shor
tions
resin
as m

5.4,
An
New

Th
tem
Woo
on v
able
seve
long
alum
and
sive
peel
A w
Met
toug
has
subr
cont
wat
seve
able
the
—A

5.4
S

degree 3 in reached the paint is considered to require renewal.—RPI.

5.4, 6.3, 6.4
Painting of Non-Ferrous Metals. G. T. Dunkley. *Mech World*, **123**, 653-657 (1948) June 4.—BL.

5.4
Barium Potassium Chromate Pigment in Metal Protective Paints. A. I. Eickhoff & L. M. Kebrich. *Paint, Oil Chem. Rev.*, **112**, No. 9, 18-20A+ (1949).

$K_2Ba(Cro_4)_2$ has been developed as an anti-corrosive pigt. The preferred method of manufacture is by heating finely ground $K_2Cr_2O_7$ and $BaCO_3$ at 650° C, followed by grinding. X-ray diffraction pattern suggests that the compd. crystallizes in the tetragonal system. The material has suitable pigt. properties for incorporating into a primer. The good protection afforded to steel, aluminum and magnesium is considered to be due to the action of water-sol. chromate (produced by leaching with water) on the substrate.—RPI.

5.4
Principles of Protecting Metals with Organic Coatings. A. J. Eickhoff and W. E. Shaw. *Corrosion*, **4**, 463-475 (1948) Oct.—BL.

5.4, 2.2
Zinc Chromate Versus Red Lead for Metal Primers. T. B. Brown. *By Gum!* (USA). **20**, No. 5, 5-7+ (1949) March-April-May.

Zinc chromate is considered superior to red lead as a rust-resistant primer. This article stresses the still greater efficiency of zinc chromate primers which are entirely free from soluble salts; exposure tests which illustrate this are described.—ZDA.

5.4, 1.6
A Glossary of Terms Used in the Paint, Varnish and Allied Trades. H. W. Chatfield. *Oil Colour Trades J.*, **116**, No. 2647, 112-6 (1949) July 8.

The concluding installment of this useful glossary, which is to be published shortly in book form, includes definitions of zinc chrome, driers, dust, oxide, resinate, stearate and sulphide, as well as many other terms.—ZDA.

5.4, 4.6, 3.3
Antifouling Treatment. *Chem. and Eng. News*, **27**, No. 10, 712 (1949) Mar. 7.

The Metallist protective coating system for metals, developed by C. A. Woolsey Paint and Color Co., is based on vinyl and other plastic resins, and is able to withstand the effects of the most severe acids, chemicals, and salts for long periods. It is applicable to steel, aluminum, galvanized iron, and ferrous and nonferrous alloys. It contains abrasive qualities said to resist chipping or peeling despite the roughest treatment. A washcoat primer is first applied, then Metalist anticorrosive, which provides a tough barrier coat. The Metalist system has protected ship bottoms and other submerged surfaces for two years of continuous immersion even in tropical waters where fouling corrosion are most severe. Its quick drying properties enable almost uninterrupted application on the metal with a minimum lay-up time. —ALL.

5.4
Spot-Welding Varnishes for Corrosion

Prevention. F. Erdmann-Jesnitzer. *Technik*, **3**, No. 9, 416 (1948).

Spot-welding varnishes contain electrical conductive materials such as graphite, iron oxides, and soot. After welding, the varnish covers the spot to protect it from corrosion. The quality of these spot welds is said to be the same as that of those without varnish.—MA.

5.4, 1.3
The Role of Protective Coats in the Conservation of Metals. U. R. Evans. Paper before United Nations Scientific Conf. on Conservation and Utilization of Resources, New York, 1949. United Nations Economic and Social Council, May 17, 1949, 12 pp. *Sheet Metal Ind.*, **26**, No. 270, 2133-2134 (1949) Oct. (Abstract)

Paints do not give best results when applied over rust or broken mill scale. For protection of steel structures, some authorities favor grit-blasting, followed by spraying with aluminum or zinc from a pistol and finally by painting. Exposure tests carried out by independent, scientific bodies are of great value, but owners of metal-work should also carry out comparative tests on their own structures.—INCO.

5.4, 8.8, 7.5
Corrosion-Resistant Cements. V. Evans. Paper before Jt. Mtg. of Road & Builders Mats. Group and Plastics Group, Nov. 20, 1947. *Chem. & Ind.*, **1948**, No. 20, 307-311, May 15.

Discussion of the properties of deterioration-resistant cements such as ciment fondu, Portland, silicate, sulfur, bitumen, silicon ester, latex and synthetic resin cements. The main application is for use as flooring for many industrial processes such as metal-pickling operations, dipping and etching. Other uses include gutters and channels and deterioration-resistant linings for tanks and chimneys. 7 references.—INCO.

5.4, 7.5, 8.8
(Electroplating) Tank Linings and Insulating Materials. V. Evans. *J. Electrodepositors' Tech. Soc.*, **24**, 129-143

(1949). *Met. Ind.*, **75**, No. 5 & 7, 86-8, 126-8 (1949) July 29 and Aug. 12.

The first part of the paper reviews briefly the properties of the following lining materials: chemically resistant asphalt, natural rubber, ebonite, synthetic rubbers, lead, and varioius synthetic-resin linings applied as coating films, flexible sheet or as sheet possessing some rigidity. Chemically resistant bricks and various corrosion-resistant cements are also described. Brief indications are given as to the correct choice of a lining for a particular job. The second part of the paper deals with insulating materials for use either over the tank lining itself where this is conducting, or for coating plating racks or jigs so that loss of plating metal by deposition on the rack or jig is prevented. In the former application, wood, glass, or synthetic-resin sheets are suitable. The choice for the second application is more difficult as materials used not only have to withstand corrosive solutions but also thermal shock and considerable handling. Among materials mentioned are soft rubber, ebonite, paint-type coatings, tape materials, flame-applied polythene, polyvinyl chloride pastes and vinyl copolymers. The outer tank is usually of mild steel or concrete and needs to be protected against splashing; a chemically resistant asphalt is often used for this purpose.

5.4, 5.2, 5.9
Finishes for Steel Products. A. G. Gray. *Prod, Fin.*, **13**, No. 10, 50-66 (1949) July.

A critical view of a paper presented by R. L. Kenyon before a meeting of the Boston Chapter of the American Society for Metals, in which he discussed the particular uses of different finishes for steel products. Five main finishes were considered: non-metallic, such as paint or lacquer; metal coatings; non-metallic coatings on top of specially treated metallic coatings; porcelain enamel; and special finishes on stainless steel. The application of phosphating treatment before painting is

recommended, especially when applied to zinc coated steel sheets rather than to uncoated ones. Among metallic coatings, zinc and aluminum are stated to give most protection to the base metal. Hot dip galvanized coatings are improved by the addition of a small amount of aluminum to the bath, as the coating is thereby rendered more ductile. Electro deposited zinc coating may be used when a thinner coat is required. Another finish mentioned is one produced by rolling a layer of asbestos felt into the zinc coating as the sheet emerges from the bath and then impregnating the asbestos layer with a bituminous material.—ZDA.

5.4

Weather Resistance of Porcelain Enamel Exposed for Seven Years. W. N. Harrison and D. G. Moore. *J. of Res. of the NBS,* Research Paper RP **1949,** 42 (1949) Jan.

A study of the weather resistance of porcelain-enameled architectural panels was begun at the National Bureau of Standards in 1939. The study involves 864 1-foot-square panels and a like number of 4-by-6-inch laboratory specimens. A previous report (1942) gave the results after 1 year of exposure. The present paper describes the condition of the panels after 7 years of weathering at Washington, D. C., St. Louis, Mo., Lakeland, Fla., and Atlantic City, N. J. Observations made during this inspection are summarized as follows:

1. Good correlation existed between acid resistance and the percentage of initial gloss retained, the enamels with best acid resistance retaining the highest percentage of their original gloss. 2. No noticeable fading of enamels of class AA or class A acid resistance occurred, nor was there objectionable fading of class B enamels. Practically all class C and class D colored enamels, however, showed very noticeable color change. 3. In contrast to the results of the first-year inspection, which showed greatest weathering effects at St. Louis and Washington, the 7-year data indicate that the conditions at Atlantic City were slightly more severe than elsewhere on the acid resistant enamels, whereas Lakeland conditions were most severe on the nonacid resistant compositions. 4. The salt-air conditions at Atlantic City caused considerable corrosion of those parts of the panels that were incompletely covered by enamel. This corrosion caused failure of attachment lugs and in some cases failure of enamel on the face by rusting through to near the enamel-metal interface from areas of poor coverage on the back. Specimens with a thin second coat of enamel on the back were not affected in this way. 5. Where the initial coverage was complete on all parts of the panel and where no mechanical damage had occurred during exposure, protection of the metal against corrosion was unimportant on all specimens after 7 years of weathering.—ALL.

5.4, 2.3

Evaluating the Ideal Industrial Instrument Finish. A. H. Keyser, Brown Instrument Co. *Prod. Eng,* **19,** No. 5, 134-137 (1948) May.

Discussion of the characteristics required of ideal industrial instrument finish, tests for abrasion resistance, shear hardness, adhesion, appearance, humidity, water immersion and the effect of

gloss, drying cycle, and color in selection.—INCO.

5.4, 5.8, 4.2, 4.6

Barium Potassium Chromate Pigment. Merritt L. Kastens and M. J. Prigotsky. *Ind. & Eng. Chem.* **41,** No. 11, 2376-2382. (1949) Nov.

A staff-industry report on the production of the new anti-corrosive pigment developed on a semiplant scale. Years of research led to the selection of this double salt as an effective pigment on the basis of its hydrolysis to release 20 to 25% more chromate ion per unit weight than other soluble chromate pigments. The pigment has proven compatible and stable with almost all paint vehicles and pigments now in use. It is of a high degree of purity containing substantially no chlorides or sulfates which might accelerate corrosion. Tests conducted out of doors for some 7 or 8 years in atmospheric, tide range, and submerged marine environments have proven the effectiveness of this inhibitive pigment. Process details are described with illustrations and a flow sheet.

5.4

Zinc Chromate Primers. H. B. Kirkpatrick. *J. Oil Colour Chemists Assoc,* **32,** No. 347, 223-4 (1949) May.

This summary of a paper, read in Australia, begins with a short history of the development of zinc chromate to its present position as the most important single rust inhibitive pigment. The theoretical basis of this superiority lies in the fact that the iron and steel are protected from the direct action of water by the formation of a dilute solution of zinc chromate on the surface of the metal, due to the slight solubility of the zinc chromate. Under these conditions rust cannot form. The importance of proper formulation is stressed to ensure an effective rate of chromate ion extraction; the best vehicle is found to be a high phthalic linseed oil alkyd.—ZDA.

5.4, 7.2, 4.3, 8.9

Longest Oil Line Since War Completed. F. H. Love. *Pet. Eng.,* **19,** No. 9, 43-46 (1948) June.

When the pipeline between Corsicana and Patoka was laid, the line was coated and wrapped throughout, coal tar enamel being applied and wrapped with glass fiber, or asbestos felt. In corrosive areas both wrappers were used. Photographs are included.—INCO.

5.4

Phosphate-Chromate Priming Coat for Rusted Metal Surfaces. *Machinery,* **55,** No. 12, 169 (1949) Aug.

A metal primer, Ospho, can be applied directly over rusted metal surfaces. Upon application to rusted surfaces, this priming compound causes iron oxide to change to iron phosphate. When a subsequent coating of paint is applied, it attaches itself so tightly to primed surfaces that moisture and O_2 are prevented from attacking metal.—INCO.

5.4, 2.3, 6.1

The Practical Problems of Corrosion. Part XIII. The Painting of Wet Steel Surfaces. J. E. O. Mayne and U. R. Evans. *J. Soc. Chem. Ind.,* **68,** No. 7, 212-5 (1949) July.

The results of four series of tests, carried out in Cambridge, over a period of 8 years, to compare the behavior of

paint-coats applied to deliberately wetted surfaces with that of similar coats applied to dry steel, and to ascertain whether any troubles encountered in painting wet steel could be overcome by the use of emulsion paints. It was concluded that, whereas it remains advisable to apply paint to dry, clean surfaces, the dangers of water on the surface are not serious, unless it is held in crevices. No advantage was found in using emulsion paints instead of ordinary oil paints. In the linseed oil paints tested it was found that red lead had slightly superior protective properties to either iron oxide or zinc dust.—ZDA.

5.4, 1.7, 6.1

Combating Corrision of Iron and Steel. *Metallurgia,* **38,** No. 224, 104-106 (1948) June.

Discussion of the work of the corrosion committee, the practical applications of the work and the work done or in hand on protective coatings in showing the scope and practical character of the Corrosion Committee of the British Iron and Steel Research Association and its Sub-Committees.—INCO.

5.4, 4.5, 3.3, 7.2

Selecting Paints for Coating Pipe-Marine Work-Concrete Floors. G. W. Oxley, Standard Oil Dev. Co. *Petr. Interam.,* **7,** No. 5, 55-6 (1949) May.

For underground and underwater use, an oxidized asphalt enamel, is recommended as coating for pipes. To prevent penetration of marine organisms, a cement shield, synthetic rubber, a special plastic, or a metal foil shield is suggested. Vinyl, Bakelite or bituminous coatings for resistance to either immersion or moist atmospheric conditions may be used and supplemented by galvanic protection with zinc or magnesium anodes. Vinyl paints have shown good resistance to sea water and marine atmosphere. There have been various new developments in copper flake, copper oxide, and other antifouling paints as a result of latest research. Hot and cold plastics, some with vinyl constituents, have shown resistance to fouling for two years or more. Petrolatum and paraffin coatings help to prevent fouling but are not satisfactory in regard to resistance to abrasion or slightly elevated temperatures. For concrete floors where painting is required, the best results are obtained from rubber-base paints which may be applied over alkaline surfaces, or Bakelite oleoresinous paints which may be used after neutralizing alkalinity with a zinc-sulfate solution and allowing to dry completely.

5.4, 4.2, 3.3

What Is the Future of Marine Finishes? I., II., III. W. G. B. Mills. *Oil Colour Trades J.,* **116,** No. 2651, 388-92, No. 2652, 456-60, No. 2653, 526-32 (1949) Aug. 5, 12, 19.

This survey, covering the whole field of marine finishes, is written with the object of considering whether the present compositions will be outmoded by the use of sprayed metallic coatings or plastics, or by building hulls of non-corrosive metals. I deals with anti-corrosive paints and primers; including reference to zinc chromate and to zinc dust at high concentration in various media. In II the author considers the biological aspect of fouling and the formulation of suitable anti-fouling compositions. It is suggested that titanium and antimony

[right column partially cut off]

oxide ...
topsid...
to cra...
oxide ...
the us...
peller-...
effect ...
discus...
the su...
owing ...
anti-fo...
paints ...
velope...
the a...
plicat...
dual ...
in ya...
ZDA.

5.4, 4...
Me...
Metal...
A ...
of all ...
to ext...
devel...
Ohio. ...
senti...
plasti...
by ad...
produ...
other ...
of m...
and c...
esses ...
the C...
corro...
tough...
venti...
Appl...
ping, ...
of m...
stren...
cadm...
magn...
ized ...
Inc.

5.4, 4...
Ho...
ener.
Cutti...
Powe...
May. ...
Ea...
he t...
rior ...
prote...

5.4
Ru...
No. ...
W...
bake...
ite s...
hibit...
rust ...
Co.—...

5.4,...
St...
Proc...
"F...
flake...
of v...
been ...
coat...
suita...
tank...
affec...
hydr...
hol...
or ...
and ...
brus...
Cov...
per ...

oxide pigments are the most suitable for topsides of yachts as they are less liable to cracking than white lead and zinc oxide paints. In III the author mentions the use of zinc plates fitted round propeller-shafts to counter the cathodic effect of bronze propellers. He then discusses metallic coatings and stresses the superiority of zinc for this purpose owing to its length of life and mild anti-fouling properties. Anti-corrosive paints based on zinc dust have been developed recently and some of these have the advantage of being capable of application to wet surfaces. Reference to dual purpose paints and future trends in yacht finishes conclude the series.—ZDA.

5.4, 4.3, 4.4, 4.6
Metal Protection Coating. *Modern Metals,* **5,** No. 7, 36, (1949) Aug.

A new coating system for protection of all types of metals that are subjected to extreme corrosive conditions has been developed by Munray Products, Inc., Ohio. Called "Cyclon WPS", it is essentially formulated from basic vinyl plastic resins and, therefore unaffected by acids, alkalies, their salts, petroleum products, alcohols, water and many other reagents. It adheres to all types of metallic surfaces and sandblasting and other similar costly cleaning processes are generally not necessary. Since the bond is accomplished chemically, the Cyclon primer's resin impregnated, corrosion inhibiting pigments develop a tough, impermeable film completely preventing underfilm metal deterioration. Applied by brushing, spraying or dipping, the coatings air dry in a matter of minutes by solvent evaporation. Bond strength is good even with zinc, lead, cadmium, aluminum, nickel, copper, magnesium, stainless steel and galvanized metals. Mfd. by Munray Products, Inc.

5.4, 4.6
How to Recondition a Zeolite Softener. C. W. Parks, J. E. Sengel, A. F. Cuttitta, J. F. Slavinsky, C. Bachmann. *Power Generation,* **52,** No. 5, 8-83 (1948) May.

Each man gives his opinion of what he thinks is best for painting the interior of a Zeolite softener for corrosion protection.—INCO.

5.4
Rust-Inhibiting Primer. *Prod. Eng.* **19,** No. 5, 164 (1948) May.

When used between air-dried or baked finishes and base materials, Stanite spraying primer No. 66R-315A exhibits excellent adhesion and prevents rust creepage. Mfd. by Stanley Chemical Co.—INCO.

5.4, 4.3, 4.4, 8.4
Stainless Steel in Solution. *Petro. Proc.* **4,** No. 7, 821 (1949) July.

"Paraline 18-8," a paint consisting of flakes of 18-8 stainless steel in a vehicle of vinyl copolymer resin material, has been found to be a durable protective coating with high corrosion resistance, suitable for refinery piping, headers, tanks, and the like. It is said to be unaffected by aging, sunlight, petroleum hydrocarbons, fresh or salt water, alcohol, but not recommended for aromatic or chlorinated hydrocarbons, ketones, and some esters. It can be applied by brush, spray, or dip. Color is blue-grey. Coverage is from 400 to 500 sq. ft./gal., per coat, thickness one mil. Drying time,

tack free, is 10 min. No primer is required. Heat resistance is up to 250° F. Mfd. by Barber-Webb Co., Inc.—INCO.

5.4, 7.5, 8.4, 6.1
Corrosion Protection for Tanks by Reinforced Gunite Linings. *Petro. Proc.* **4,** No. 7, 784-788 (1949) July.

Reinforcing with steel mesh in the application of Guniting has provided a successful means of protecting storage tanks from corrosion, overcoming spalling which occurred when a thinner, nonreinforced Gunite lining was used. Details of the installation of reinforcing are given. Gunite protection is not usually attempted on roofs where the steel has lost two-thirds of its original weight. New steel usually is Gunited when the corrosion rate indicates an expected service of 5 years or less.—INCO.

5.4, 4.2
Fluorescent Fixture. *Power,* **92,** No. 6BG, 172 (1948) Mid-June.

HF-100 fixture has weatherizing finish, Miracoat, that is resistant to rust, corrosion and pitting. Mfd. by Sylvania Electric Products Co.—INCO.

5.4, 6.1, 1.3
Bituminous Coatings for Protecting Iron and Steel Against Corrosion. R. St. J. Preston. *Ind. Fin.* (UK) (1949), 715-8 (1949) June.

A review of existing information on bituminous coatings generally. These coatings are of three types: wholly bituminous-base media, modified bituminous-base media, and pigmented and filled compositions. The various substances which can be added to the tar or bitumen base to improve weather resistance, adhesion and appearance are discussed. Comparison of metal powder pigments shows that zinc chromate is among the best of these for the protection of light alloys and steel. Zinc oxide is mentioned as a basic corrosion inhibitor. It is suggested that the use of the cheap bituminous media, together with the more expensive types of pigments, might give a protective composition at lower cost than one containing cheaper pigments and the more expensive oil-type media.—ZDA.

5.4
Low Cost Corrosion-Resistant Coating. *Anon. Prod. Eng.* **20,** No. 6, 155 (1949) June.

A brief account of 'Zincilate,' a zinc metal-pigmented paint which is said to offer savings in the finishing of many products. The coating which can be applied by brushing, spraying or dipping has resisted the ASTM salt spray for over 1000 hours, and is being used to finish corrugated steel sheet. The coverage is about 400 sq. ft. per gallon. The coating can withstand light bending and forming, and is only locally damaged during welding. Stoving and air-drying formulations are available. The finish is a light matt grey, and can be used as a basis for decorative enamels, etc.—ZDA.
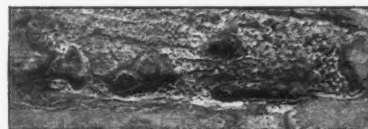
5.4, 4.2, 4.6, 5.9
Non-Metallic Coatings for the Protection of Steel. *Prod. Fin.,* **12,** No. 10, 88. + (1948) July.

Several nonmetallic protective schemes, including paints, sprayed coatings, and other nonmetallic coatings, were applied to structural mild steel and exposed to atmospheric weathering up

a 5 yr. and to sea water for a maximum of 2 yr.

Two-coat painting schemes applied to surfaces pickled by a sulfuric-phosphoric acid treatment were in good condition after 5-yr. weathering. The dull gray phosphate film in itself has little protective value except indirectly as an excellent paint base. When applied to specimens partially descaled by weathering and then wire brushed, one of the paint schemes failed in 1.6 yr. or less; pretreating this type of surface with a proprietory phosphoric-chromic acid inhibitive wash before painting did not improve the durability of the coating. In the atmospheric test, lanolin-base paints which had been hardened with synthetic resin and contained chromate pigments were satisfactory as primers over pickled steel.

A sprayed-on paint containing no volatile matter was effective in an industrial atmosphere, but showed signs of breakdown after 5 yr. in a nonindustrial atmosphere. Sprayed-on cement-asbestos, ¼-in. thick, permitted no corrosion after 5 yr. Heavy coatings of sprayed bitumen, alone or mixed with rubber or zinc, were satisfactory when continuously immersed in sea water. The addition of glass to sprayed zinc coatings did not appreciably affect their performance in sea water.

A tar-tallow-lime mixture, applied hot, failed after 3 yr. in an industrial atmosphere; this life is comparable to that of a single paint coat of about equal weight. A rubber-wax sheathing gave good results in the industrial, but irregular results in the marine atmosphere. Vitreous enamel coatings were in perfect condition, apart from minor mechanical damage, after 5 yr. in either atmosphere or 2 yr. in sea water.

The painting systems studied comprised two- and four-coat combinations of red lead or red oxide in linseed oil, a proprietory scheme of paints bound with alkyd resin media, and schemes containing prime coats of resin reinforced lanolin-base paints. The sprayed coatings tested included a paint with

no volatile constituent, cement-asbestos used for insulating purposes, powdered bitumen mixtures, and a mixture of powdered zinc with silica glass. These powdered mixes were sprayed on with a modified powder metal spraying pistol. Of the other coatings tested, the tar-tallow-lime mixture was applied hot, and the rubber-wax mixture could be molded to give a continuous sheath.

The phosphate pickle process involved descaling of the steel samples by immersion for 15-20 min. in 5-10% sulfuric acid at 60-65° C, rinsing by dipping twice into water at 60-65° C, immersion for 3-5 min. in a bath containing about 2% free phosphoric acid and 0.3-0.5% iron at 85-90° C, followed by rapid drying—PDA.

5.4, 2.3
Evaluation of Paint Films. C. J. Rolle and T. L. Dietrich. Interchemical Corp. *Analytical Chem.* **21**, No. 8, 996-997 (1949) Aug.

A method is presented for resolving the stripping force measurements of organic coatings on metal surfaces into their basic factors of plasticity and adhesion. The application of this method should make the adherometer a useful research tool in the evaluation and formulation of organic finishes.—TDD.

5.4, 4.2
Moisture-Resistant Coatings for Metal. W. F. Singleton and W. C. Johnson. *Ind. and Eng. Chem.,* **41**, 749-53 (1949) Apr.

Data for a range of polymeric coatings, are presented on permeability, adhesion to certain metals including cadmium, and moisture resistance in the presence of alkali. The effect of pigment additions is described and compared with that in oleo-resinous paints. The polymeric paints are more resistant to alkali than oleo-resinous ones, but have a similar permeability to a phenolic-tung oil varnish. Inert pigments reduce the permeability, but zinc yellow raises it, in contrast to its effect on oil varnishes. The addition of inert pigments increases

the adhesion of the polymers to the metals tested, while zinc yellow has little effect.—ZDA.

5.4, 4.6
Zinc Yellow Primers. J. F. H. van Eijnsbergen. *Chem. en Pharm. Tech.* (Dordrecht) **1949**, No. 4, 221-5; *Chem. Abs.,* **43**, 5605 (1949).

Corrosion tests in sea water on primers containing $4ZnO.K_2O.4CrO_3 3H_2O$ and a linseed-oil-modified alkyd show that the presence of up to 2 volumes of talc per volume of pigment is permissible; 30 to 40 percent by volume of pigment in the dry film is satisfactory. The behavior of various extenders and vehicles is described.—ZDA.

5.4, 4.2, 4.1, 2.3
Specifications and Application of Wrinkle Finishes. W. A. Waldie, New Wrinkle, Inc. *Elec. Mfg.,* **44**, No. 2, 106-111+ (1949) Aug.

Discussion of special properties and methods of application from standpoint of original equipment designer. Table of tests show that wrinkle finishes are inferior to standard air-drying enamels in cold and boiling water immersion tests but are superior in salt spray resistance and abrasion resistance tests. As a result of its salt spray resistance, wrinkle is used on marine and aircraft instruments. Driers are used to produce surface skin and are metallic catalysts, consisting of compounds of cobalt, lead, of manganese. Cobalt produces quickest formation of skin. Lead is valued more as a film hardening agent and is frequently used in combination with cobalt. Copper bronze powders give gold and copper color effects, but black is still used in largest volume.—INCO.

5.4, 5.8
Rust Inhibitor. *Welding Eng.,* **34**, No. 8, 64 (1949) Aug.

Combination rust-inhibitive paint primer and finish coat called Totrust is claimed to go deep into rusted pits and stop further corrosion at its source. It may also be painted over damp surfaces since it allows moisture to come through by capillary action. Coverage is 800 to 1,000 ft. per gallon. Mfd. by Wilbur & Williams Co.—INCO.

5.4, 4.5, 7.9
Neoprene Goes Underground. *Wire & Wire Prod.* **23**, No. 3, 249 (1948) March.

Neoprene jackets are tough, resilient, not easily damaged, do not rust or rot and are not affected by galvanic action or corrosive effects of acid and alkaline soils. Used to replace lead on cables.—INCO.

5.4
Long Life and Color, Too. A. E. Young, Dow Chemical Co. *Dow Diamond,* **12**, No. 4, 1-5 (1949) Aug.

Industrial plants now use paints containing styrenated oils to combat maintenance problems on metal structures. These paints keep their color longer and show improved resistance to surface failures.—INCO.

5.4, 3.4, 4.6
Blistering of Paint Films on Metal. P. J. Gay. Oil Col. Chem. Assoc. Conf., Rothesay, 1949, Preprint, 8 pp.

Expts. with painted metal immersed in salt water (usually sea water) are described. Often the steel under blisters is bright and uncorroded. Blister water is found to be alkaline and to contain

less chloride than the surrounding sea water. It is suggested that films act first as swelling gels and then as imperfect semi-permeable membranes. In the initial stages local electrolytic cells are farmed, and hydroxyl ions concentrate at cathodic areas and attack the paint/metal interface and destroy adhesion. Thereafter blisters expand osmotically. An explanation of the mechanism of corrosion creep under wet paint films is offered.—RPI.

5.4

Flame-Spraying Corrosion Resistant Linings. A New Protective Technique. H. W. Greenwood. *Ind. Chemist*, **24**, 743-745 (1948) Nov.—BL.

5.4, 6.7

Flake Metal Powders and Paint. H. W. Greenwood. *Paint Manufacture*, **19**, 301-303, 314 (1949) Sept.

Describes the development and properties of zinc, nickel, stainless steel, and silver-flake powders.—BLR.

5.4, 8.9

Zinc Metal Pigmented Paints. A. W. Hoskings. *Ship & Boat Builder*, **3**, 17 (1949) June; *J. Brit. Shipbuilding R.A.*; **4**, No. 8, 384 (1949).

Zinc-pigmented paints are best suited for covering patches of bare steel or for replenishing the zinc in a coating which has been unevenly attacked. They can be applied over adherent rust and mill scale. Zinc protects steel electrochemically, and a film of corrosion products can form on the zinc which insulates it from further attack. Also, zinc-dust paints have a limited reducing action on adherent rust. Two main types of paint most likely to give adequate marine protection. The second type, based on a mixture of zinc dust and ZnO, is

frequently used for painting drinking water tanks on ocean-going vessels.—RPI.

5.4

Industrial Application of Natural and Synthetic Resins. H. H. Howard. *Can. Pt. and Varnish*, **22**, 36-37, + (1948) May.—BL.

5.4

Protective Value of Sprayed Bitumen Coatings. *Ind. Fin.* (Brit.), 1949, 332-8.

A process for applying heavy bituminous coatings to steel, concrete and brick surfaces by spraying a specially prepd. bitumen in powder form is described. Details of equipment, some possible applications of the method, and approx. cost are given.—RPI.

5.4

Scatter-Proof, Rust-Proof Coating. *Ind & Welding*, **22**, No. 10, 78 (1949) Oct.

Protect-O-Metal No. 8 is a new coating to protect parts and raw stock from rusting prior to welding and between operations. Applied with brush, spray or by dipping, it dries in less than an hour to a thin, transparent coating which prevents rust up to six months in the weather and up to two years on steel stored indoors. Protect-O-Metal No. 8 need not be removed after welding as it serves as a good base for subsequent painting. Mfd. by G. W. Smith & Sons, Inc.—INCO.

5.4, 3.6, 5.2, 3.7, 4.6

Zinc as an Anti-Corrosive (in Paint). *Internat. Ind.*, **29**, No. 2, 76-77 (1948) Feb.

Zinc dust used as a pigment in paint protects any metal exposed by scratch independently of the initial mechanical covering provided by the paint. It is generally assumed that its function is to act as anode in any electrolytic cell which may be established. To discover whether any protection is afforded when a particle of zinc is separated from the iron surface by a drop of water, mild steel rod was immersed side by side with zinc sheet in various types of water. In sea water, the steel remained bright and uncorroded during 48 hr. when an external wire connected it with the zinc, while an unprotected steel rod rusted in 2 hr. and was heavily coated after 48 hr. Introduction of external resistance into the circuit reduced the current flowing through wire, but destroyed the protection afforded by the zinc only when it was over 100 ohms. Various other conditions of immersion of steel and zinc in distilled water are described with results. Conclusions are that if zinc is applied so that circuit is not complete, presence of zinc will retard rate of corrosion but not entirely prevent it. Zinc dust incorporated into paint film is not the good electrical conductor it is sometimes supposed to be. Settling of zinc dust in paint is another problem. Purity of zinc is important. A 99.95 zinc will dissolve in N/10 hydrochloric acid in the time taken by a 99.99 zinc to lose only half its weight. Curves show potential of steel rod in untreated distilled water and results for a zinc strip immersed several hours before steel was introduced.—INCO.

5.4, 7.1

Paint for Oil Duct Systems for Steam Turbines. (In Russian.) E. V. Iskra and V. I. Volkov. *(Kotloturbostroenie Boiler*

and Turbine Manufacturer), 1949, 30-32, Mar.-Apr.

Different paints and lacquers for the above were investigated. Method of testing is described. On the basis of the results, the best paint for exposure to oil-containing moisture is indicated. Chemical and physical properties of this paint are presented. 20 ref.—BLR.

5.4, 5.9

Relations Between the Metal Base and the Film as the Basis for the Anti-Corrosion Effect of Protective Coatings. O. Jordan. *Angew. Chem.*-B 20, 292-5 (1948) Nov.

In a survey of inorganic and organic protective coatings, the measures that can be taken to improve rust protection and the requirements of protective coatings such as pore density, water and steam permeability, adhesiveness, and passivity are discussed. The cleaning of the metal surface with various acids, the elasticity and hardness of the coating films, the influence of the binding agent and examples of the use of synthetic coatings are also considered.

5.4, 3.5

Diffusion of Electrolytes Through Organic Membranes. W. W. Kittelberger. *J. Phys. & Coll. Chem.*, **53**, 392-409 (1949) Mar.—BL

5.4, 2.1

Improved Recording System for the Results of Weathering Tests of Paint Film. J. L. Little. *Paint Notes*, **4**, No. 2, 48-9 (1949).

The lay-out of index cards for filing records of examination of exposed panels is described. Provision is made for details of formulation of paints, number of coats, exposure conditions, etc., and space for 13 observations comprising gloss, chalking, cracking, etc.—RPI.

• Packaging

5.6

Corrosion Proofing. Kraft Paper Treated for Packaging Use. Nox-Rust Chemical Corp. *Ind. Equip. News*, **17**, 2 (1949) Jan.—BL.

EQUIPMENT

• Engines and Turbines

7.1

Engine Bearing Failures. J. M. Stokely, California Research Corp., San Francisco, Calif., SAE Inc., New York, N. Y., Preprint No. 222 (1948) Aug.

Bearing failures can be easily identified under the microscope as fatigue failure, corrosion failure, or a combination of both. Most of the corrosion failures in the field occur in cadmium-base and copper-lead bearings. Lead-base bearings with less than 5% tin or 0.5% silver are subject to corrosion, but high lead babbitts with greater tin or silver content give little trouble. Tin-base babbitt is practically immune to corrosion since rapid fatigue failure occurs at a temperature below that at which corrosion begins.

Among the various factors responsible for either type of failure, high oil or bearing temperatures are the most damaging. Abnormally high temperatures may be caused by 1) plugged or impaired

circula
quently
system
may be
ing and
contac
vealed
4) plu
holes
bearing
7) an o

Othe
peratu
chanica
from
bearing
camme
whips,
of bea
4) abr
with w
bond,
bearing
facturi

Con
corros
tures,

INDEX TO ADVERTISERS
AUGUST, 1950

Vol. 6   **No. 8**

circulation of radiator or oil coolers, frequently caused by neglect of the coolant system, 2) an overloaded engine, which may be prevented largely by driver training and automatic transmissions, 3) poor contact between bearings and seats, revealed by burned oil on bearing backs, 4) plugged oil channels or bearing oil holes being out of line, 5) insufficient bearing clearances, 6) poor timing, and 7) an oil with too high a viscosity.

Other factors, in addition to high temperatures, responsible for fatigue or mechanical failures include 1) pounding from crankshaft misalignment, excess bearing clearances, out-of-round or cammed crankshafts and crankshaft whips, 2) improper fit or misalignment of bearing, 3) rough or tapered journals, 4) abrasives in the oil, 5) replacement with wrong bearing material, and 6) poor bond, lead segregation in copper-lead bearings, or other metallurgical or manufacturing defects.

Conditions which may cause bearing corrosion include 1) excessive temperatures, the rate of corrosion doubling with each 5° F rise above 230° F oil sump temperature, 2) excessive fuel dilution, particularly of Diesel fuel, 3) excessive time between drainage, 4) previous use of inferior oil, 5) cold operation, the corroding agent apparently being condensed water and mineral acids from the decomposition products of the fuel, and 6) poor lubricants, or good lubricants improperly prescribed.

The combination of improved bearing manufacturing methods, good maintenance, trained drivers, and modern compounded heavy-duty oils have eliminated many bearing troubles.—PDA.

• Coils and Heat Exchangers

7.4
Self-Scaling Evaporators. *Shipbuilding and Shipping Record,* **72**, 95 (1948) July 22.

One of the biggest difficulties in the operation of evaporators and distillers is the removal of the scale which forms on the heating surface. Attention may therefore be drawn to a self-scaling type of evaporator having a capacity of 1100 gallons of fresh water per day which has recently been approved by the American Coast Guard after a 2000-hour test without overhaul, for use on lightships. The still, as it is termed, is of all-Monel construction and comprises an upright cylindrical shell arc-welded from ⅛-inch Monel sheet. Inside are two chambers provided with vertical corrugations arc-welded from light-gauge Monel sheet which serve as interchangeable evaporator and condenser sections. Live steam inside the evaporator section boils sea water in the shell around it, the vapor passing through a cyclonic separator which takes out the entrained particles of water. It then condenses on the fin-like corrugations of the condenser section which is kept cool by the entering feed water from the sea. When it is desired to descale, steam is fed into the evaporator section which flexes the corrugations outward. Cold sea water is then let into the shell causing instantaneous condensation of the steam which, it is stated, produces a nearly perfect vacuum that sucks the corrugations inward. This flexing back and forth of the corrugations cracks off the scale which is then expelled. The purity of the water produced by these stills is said to be 0.20 grains per gallon which is considerably better than the 0.25 grains maximum set by the U. S. Department of Public health.—TIME.

INDUSTRIES

• Group IV

8.4
Mitigation of Corrosion on City Gas Distribution Systems. A. D. Simpson, Jr. *Corrosion,* **5**, No. 2, 59-69 (1949) Feb.

Steel gas mains have been systematically protected cathodically, with galvanic anodes as a source of protective current, using zinc or magnesium anodes depending on requirements.—BNF.

8.4
Pipeline Corrosion Control with Cathodic Protection. K. D. Wahlquist. *World Oil,* **128**, No. 10, 163-4+ (1949) Feb. 1.

Cathodic protection of buried and submerged pipe lines is reviewed, and the various types of equipment employed are described briefly.

8.4
Specific Problems, Methods of Attacking for Best Success. R. W. Tryon, Esso Standard Oil Co. Paper before API Div. of Refining Mid-year Mtg., Houston, Texas. *Oil & Gas J.,* **47**, No. 50, 85-86 (1949) Apr. 14.

Discussion of maintenance problems in petroleum refineries and the methods of preventing them, including use of cathodic protection and non-metallic linings for large vessels. Carbon and scrap steel are two types of anodes commonly used to protect piping in buried trenches. Gunite, over a metal-base mesh, provides protection against erosion and internal corrosion.—INCO.

8.4
Some Aspects of the Corrosion Problem in the Petroleum Industry. An Informal Discussion. K. A. Spencer, A. G. Ellison, and F. G. Dickinson. Discussion by Council of British Manufacturers of Petroleum Equipment. *Brit. Petro. Equipment News,* **1**, 14-17 (1949) Mar.

The discussion includes reference to the use of Ni-Cr austentic steels of various types, and to the advantages of cupro-nickel condenser tubes.—INCO.

8.4
Metals Used in Oil Refining. Comparative Resistance to Heat, Stress and Oxidation. W. I. Pumphrey. *Chemical Age,* **60**, 853-856 (1949) June 11.

Review of typical operations involved at the various stages of oil refining, and discussion of steels used to resist corrosion and/or heat. Reference is made to Ni-Cr corrosion-resisting steels, alloy cast irons and low-alloy steels.—INCO.

CORROSION LITERATURE

Available From

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

BIBLIOGRAPHIC SURVEY OF CORROSION, 1945

Single copy postpaid to members of the Association $4.00
To non members of the Association 5.00

JOINT SYMPOSIUM ON CATHODIC PROTECTION

To members of the Electrochemical Society and National Association of Corrosion
Engineers, per copy 6.00
To all others, per copy 8.00

PROCEEDINGS, FIRST ANNUAL MEETING, NACE

Single copy postpaid to members of the Association 3.00
To non members of the Association 6.00

DIRECTORY, AMERICAN COORDINATING COMMITTEE ON CORROSION

Single copy, postpaid 2.00

FIRST INTERIM REPORT ON GROUND ANODE TESTS
of Technical Practices Committee No. 3 "Anodes for Impressed
Currents"

Single copy postpaid to members of the Association 3.00
To non-members of the Association 5.00

CONTROL OF PIPE LINE CORROSION
by O. C. Mudd
Single copy, postpaid $1.25
(Five or more copies to one address, postpaid at $1.00 per copy)

**SELECTED BIBLIOGRAPHY ON
SALT SPRAY TESTING**
by Lorraine R. Voigt
Single copy, postpaid .... $ .50

**THE MITIGATION OF CORROSION ON
CITY GAS DISTRIBUTION SYSTEMS**
by A. D. Simpson, Jr.
Single copy, postpaid .... $ .50

**CAUSES OF CORROSION IN AIRPLANES
AND METHODS OF PREVENTION**
N. H. Simpson
Single copy, postpaid .... $ .50

**THE USE OF AMMONIA IN CONTROL OF
VAPOR ZONE CORROSION OF STORAGE TANKS**
by F. T. Gardner, A. T. Clothier and F. Coryell
Single copy, postpaid .... $ .50

CORROSION Magazine
Most back issues are still available
Single copies to members, postpaid .... $ .50
Single copies to non-members, postpaid ...... $ .75

TO: NATIONAL ASSOCIATION OF CORROSION ENGINEERS, 919 Milam Bldg., Houston 2, Texas

Please send me the following publications:

Quantity

(   ) Bibliographic Survey of Corrosion
(   ) Joint Symposium on Cathodic Protection
(   ) Proceedings, First Annual Meeting
(   ) Directory, American Coordinating Committee on Corrosion
(   ) First Interim Report On Ground Anode Tests
(   ) Control of Pipe Line Corrosion

(   ) Selected Bibliography on Salt Spray Testing
(   ) The Mitigation of Corrosion on City Gas Distribution Systems
(   ) Causes of Corrosion in Airplanes and Methods of Prevention
(   ) The Use of Ammonia in Control of Vapor Zone Corrosion of Storage Tanks
(   ) CORROSION Magazine [Indicate month (   )
          and year (   )]

Name ....

Street ....

City .... Zone ..... State ....

I am (not) a member of NACE.
Check one: I wish to be billed for
              these publications at . $ ....

I am enclosing a check for $ ....